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Importation of Japanese Unshu Orange Fruits (*Citrus reticulata* Blanco var. *unshu* Swingle) into Citrus Producing States

Pest Risk Assessment

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I. Introduction

A. General

This pest risk assessment is part of an overall analysis of risks associated with importations of Japanese Unshu orange fruits (*Citrus reticulata* Blanco var. *unshu* Swingle, also known as Satsuma). The other primary components of the analysis are risk management and risk communication. Although this pest risk assessment offers brief recommendations, it does not present APHIS' decisions regarding importation of Unshu orange fruits from Japan, nor does it present a risk management plan. The bulk of the risk management phase of the Unshu orange fruit risk analysis will occur following completion of this document. APHIS' decisions and risk management program will use this pest risk assessment as a management tool.

This is a "comprehensive risk assessment" because it includes:

- consideration of both indigenous and exotic pests
- qualitative assessment of pest risk potential
- pest data sheets for selected pests
- scenario analysis of pest establishment
- quantitative estimates of likelihood of establishment for selected pests
- management recommendations

This risk assessment was "pathway-initiated" (*i.e.*, the assessment was initiated by a request for permission to import a particular commodity). In this case, importation of Unshu orange fruits from Japan is a potential pathway for introduction of plant pests. The draft FAO definition of pest risk assessment is "...determination of whether a pest is a quarantine pest and evaluation of the likelihood and consequences of its introduction". Both issues are addressed in this pest risk assessment.

B. Historical perspective, Regulatory Authority and Current Importations

The impetus for restrictions on the importation of Japanese Unshu orange fruits was citrus diseases. Because of these diseases, citrus fruits from many countries are denied entry under Title 7, CFR 319.28 or simply Quarantine 28. However, for many decades we have allowed the importations of Unshu orange fruits from Japan, despite the quarantine significant citrus canker disease (*Xanthomonas campestris* pv. *citri*) which has long occurred there. We use a series of independent safeguards to reduce the threat of disease introduction. This safeguard system is described in CFR 319.28. First, the Unshu orange is moderately resistant to citrus canker. Second, we have approved only those production areas in Japan in which solely Unshu oranges are grown, and each area must be surrounded by a buffer zone containing only Unshu or other resistant varieties of citrus. Then, all fruits are subject to a strict inspection protocol, and to treatment with 200ppm sodium hypochlorite as a further precaution. Finally, there is no record of citrus canker disease on Unshu oranges from approved groves. In addition, we allow Unshu orange fruits to be distributed only to certain states. Until 1987, we allowed these fruits to be distributed only in Alaska, Hawaii, Washington, Oregon, and Idaho. In 1987, at the request of Japanese officials, we amended foreign and domestic regulations to allow the distribution of Unshu orange fruits to a total of 38 states, excluding essentially the southern tier of States.

We currently restrict distribution of Unshu orange fruits to keep them from commercial citrus-growing areas of the U.S. The general work plan for Unshu orange is listed in the Japanese Unshu Orange Program, a work plan which describes requirements for shipment of Unshu orange fruits to non citrus production states of the U.S. Currently, in addition to routine pest control by growers:

1. The production areas are inspected every year by PPQ and MAFF.
2. The packing areas are inspected every year by PPQ and MAFF.
3. Due to high rejection rates for exotic mealybugs, Japanese growers are voluntarily fumigating their fruit with methyl bromide. These treatments are unsupervised.
4. The fruit are given a mandatory chlorine (sodium hypochlorite) dip.
5. The fruit are brushed physically to remove loose items.
6. The fruit are physically inspected by PPQ personnel in Japan (organisms targeted during inspection include: *X. campestris* pv. *citri*, *Unaspis yanonensis*, *Planococcus kraunhiae*, and *Pseudococcus cryptus*, and any other insects or diseases not known to occur in the U.S.)
7. The fruit are given a final inspection at port of entry, usually in Seattle, WA.

In summary, APHIS' regulatory authorities regarding importation of fruits are:

1. Quarantine 56 (Title 7, Code of Federal Regulations (CFR), §319.56 to §319.56-8): restricts importation of fruits
2. Quarantine 28 (7 CFR §319.28) allows importation of Unshu orange fruits into certain areas.
3. Domestic Quarantine 83 (7 CFR §301.83) prohibits interstate shipment of Unshu orange fruits from quarantine areas (38 States) to 12 States: AL, AZ, CA, FL, GA, LA, MS, NC, NM, NV, SC, TX plus four territories.
4. §301.83 [Amended] removes seven States (AL, GA, MS, NV, NM, NC, SC) from prohibited list. The remaining states are: AZ, CA, FL, LA, TX. Unshu orange fruits cannot go to these states or the four territories.

C. Proposed Action

This pest risk assessment covers importation of Japanese Unshu orange fruits into the five citrus-producing States. Currently, Unshu orange fruits from Japan are enterable into all States in the continental U.S. except Arizona, California, Florida, Louisiana and Texas (these five States are hereby defined as the citrus-producing States). The Japanese government has asked for permission to import to all areas of the U.S. including these citrus-producing States. It has also been proposed that an official preclearance program be established for exports of Japanese unshu orange fruits to the U.S.

D. Assessment of Weediness Potential of Unshu Orange

The initial step after receiving a request for importation of a commodity is to analyze the weediness potential of the species to be imported. Table 1 shows how we assessed weediness potential and presents our findings for Unshu orange. Because we found that the weediness potential of the Unshu orange was sufficiently low, we proceeded with this risk assessment.

E. Methods Summary

After determining that the commodity poses no significant risk as a weed, the pest risk assessment proceeds with five basic steps:

1. Pest List

The pest list includes limited pertinent information on the biology and distribution of each pest and selected references. We paid particular attention to pest—commodity association, current distribution, regulatory history, and interception records at U.S. ports.

Table 1: Process for Determining Weediness Potential of Commodity

Commodity: Japanese Unshu orange (*Citrus reticulata* Blanco var. *unshu* Swingle, also known as Satsuma)

1. Assess the weediness potential of the imported species.

Answer Yes or No:

Is the species listed in:

NO	*Geographical Atlas of World Weeds*
NO	*World's Worst Weeds*
NO	TCENW list
NO	*Economically Important Foreign Weeds*
NO	Weed Science Society of America list?
NO	Is there any literature reference indicating weediness (*e.g.*, *AGRICOLA*, *CAB*, *Biological Abstracts*, *AGRIS*; search on "species name" combined with "weed").

IF: * 1. All of the above answers are **no**,

THEN: proceed with the pest risk assessment.

2. The answer to **one** of the above is yes,

THEN: proceed with the pest risk assessment and incorporate findings regarding weediness into the Risk Elements described below.

3. The answer to **two or more** of the above is yes,

THEN: Consult authority under the Federal Noxious Weed Act for listing plant species as a noxious weed.

2. Pest Risk Potential (selected pests)

Certain pests were analyzed more extensively than others (see section II.B.). The initial phase of the extended assessment involved assigning risk values for five different risk elements for each pest. Criteria for estimating risks based on the risk elements are largely qualitative but we assign numerical values (0, 1, 2, or 3 points) for each element. A summation over each component risk value provides a numerical estimate of pest risk potential for each pest.

3. Pest data sheets (selected pests)

For pests satisfying certain criteria (see section II.B.) we collected more complete information on their biology. We present our findings in the form of "pest data sheets" (see Appendices).

4. Extended Assessment (selected pests)

Individual pests (*e.g.*, *X. campestris* pv. *citri*) or groups of pests with similar biologies (*e.g.*, three species of mealybugs) are analyzed using quantitative risk assessment techniques. The extended assessment consists of scenario analyses and Monte Carlo simulations to estimate the probabilities of establishment of pests presenting the greatest risk (*i.e.*, quarantine pests) to cultivated and noncultivated U.S. plants.

5. Recommendations

This document presents a pest risk assessment. APHIS' complete pest risk analysis will also include an analysis of risk management alternatives. Although this assessment does not present APHIS' assessment of risk management alternatives, it concludes with recommendations for pest risk management.

II. Pests Associated with Citrus in Japan

A. Pest List

Our pest list for Japanese Unshu orange is given in Table 2. All pests listed in Table 2 occur in Japan (two eradicated pests are also listed). The list includes both nonindigenous (*i.e.*, does not occur in the U.S.) and domestic (*i.e.*, occurs in the U.S.) pests associated with citrus in Japan. For each pest in Table 2:

1. We state explicitly that the pest occurs in Japan.
2. We list the known distribution in the continental U.S. We considered each of the five citrus producing States separately. All other States in the continental U.S. are referred to collectively as "Other".
3. We provide limited pertinent comments regarding the biology and regulatory history (*e.g.*, interception records), all pests intercepted at U.S. ports on shipments of Unshu orange fruits from Japan are included on the pest list.
4. We provide selected references on the biology/distribution of the pest.

While preparing the list, we assumed that all Quarantine 56 conditions would be in effect: only fruit would be shipped and absolutely no stems or leaves or any other kind of plant material would accompany the fruit; we assumed that all traces of stems and other plant material would be removed before packing. This assumption affects risk management.

To be considered in more detail pests must reasonably be expected to remain on the fruit during processing in order to have an opportunity to be shipped along with the fruit.

Table 2. Pest List, Japanese Unshu Orange: Pathogens

Pathogens: Scientific Name[1] and Common Name of Disease	Distribution[2]	Comments[3]	Reference(s)
Fungi			
Alternaria citri Ellis & N. Pierce in N. Pierce Black rot (Alternaria rot)	JP AZ CA FL TX OT	c f	Anonymous, 1966; Knorr, 1973; Reuther, *et al.*, 1978; Whiteside, *et al.*, 1988
Ascochyta pisi Lib. Freckle	JP AZ CA FL LA TX OT	c f	Whiteside, *et al.*, 1988
Aspergillus niger Tiegh. Aspergillus rot	JP AZ CA FL TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Botrytis cinerea Pers.: Fr. Gray mold	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Capnophaeum fuliginodes (Rehm) Yamamoto (Syn.: *Capnodium fuliginodes* Rehm) Sooty Mold	JP	b c	Anonymous, 1966
Cercospora penzigii Sacc. (Syn.: *Cercospora fumosa* Penz.) Sweet orange leaf spot	JP AZ CA FL TX OT	a f h	Fawcett, 1936; Whiteside, *et al.*, 1988
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. in Penz. (Syn.: *Gloeosporium foliicola* Nishida) Postbloom fruit drop (Anthracnose)	JP AZ CA FL TX OT	c f	Anonymous, 1966; Knorr, 1973; Whiteside, *et al.*, 1988
Cylindrocladium citri (Fawcett & Klotz) Boedjin & Reitsma Decay of citrus fruits	JP CA FL	f h	I.M.I., 1993
Diaporthe citri F.A. Wolf (Syn.: *Phomopsis citri* H. Fawc.) Citrus melanose (Stem end rot)	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988; Yamato, 1971
Diaporthe rudis (Fr:Fr) Nitschke (Syn.: *Diaporthe medusaea* Nitschke) Melanose-like blemish	JP AZ CA FL TX OT	c f	Whiteside, *et al.*, 1988; Yamato, 1979
Dothiorella gregaria Sacc. Dothiorella gummosis (Dothiorella rot)	JP CA	c f	Whiteside, *et al.*, 1988

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Elsinöe fawcettii Bitancourt & Jenk. Citrus scab	JP FL LA TX OT	c f	Anonymous, 1966; C.M.I., 1974b; Whiteside, *et al.*, 1988
Erythricium salmonicolor (Berk. & Broome) Burdsall (Syn.: *Corticium salmonicolor* Berk. & Broome) Pink disease	JP FL LA OT	a f	Anonymous, 1966; Oniki, *et al.*, 1985; Whiteside, *et al.*, 1988
Ganoderma applanatum (Pers.) Pat. (Syn.: *Fomes applanatus* (Pers.) Gill) Butt rot	JP AZ CA FL LA TX OT	a c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Geotrichum citri-aurantii (Ferraris) E.E. Butler Sour rot	JP AZ CA FL LA TX OT	c f	Knorr, 1973; Whiteside, *et al.*, 1988
Guignardia sp. (Syn.: *Phoma citricarpa* McAlpine var. *mikan* Hara) (Nonpathogenic form)	JP FL	f	C.M.I., 1990; McOnie, 1964, 1967
Helicobasidium mompa Tanaka Violet root rot	JP	a	Anonymous, 1966
Mycosphaerella citri Whiteside Greasy spot	JP FL TX	a c f	Ieki, 1986; Whiteside, *et al.*, 1988
Mycosphaerella horii K.Hara (Syn.: *Phyllosticta curvispora* Hori) Gray leaf spot	JP FL	a f	Anonymous, 1966; Whiteside, *et al.*, 1988; Yamada, 1956
Pellicularia koleroga Cooke (Syn.: *Corticium koleroga* (Cooke) Hõhn.) Thread blight	JP FL LA TX OT	c, f	C.M.I., 1988; Whiteside, *et al.*, 1988
Penicillium digitatum (Pers.:Fr) Sacc. Green mold	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Kuramoto, 1979; Whiteside, *et al.*, 1988
Penicillium fructigenum Takeuchi Penicillium rot	JP	c	Anonymous, 1966

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Pathogens: Scientific Name[1] and Common Name of Disease	Distribution[2]	Comments[3]	Reference(s)
Penicillium italicum Wehmer Blue mold (Contact mold)	JP CA FL LA TX OT	c f	Anonymous, 1966; Kuramoto, 1979; Whiteside, *et al.*, 1988
Phoma pinodella (L.K. Jones) Morgan-Jones & K.B. Burch (Syn.: *Ascochyta pinodella* L.K. Jones) Freckle	JP CA FL OT	a f	Whiteside, *et al.*, 1988
Phytophthora cactorum (Lebert & Cohn) Schröt. Collar rot	JP AZ CA FL LA TX OT	c f	Anonymous, 1966
Phytophthora citrophthora (R.E. Sm. & E.H. Smith) Leonian Brown rot	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Phytophthora nicotiane Breda de Haan var. *parasitica* (Dastur) G.M. Waterhouse (Syn.: *Phytophthora parasitica* Dastur) Foot rot, gummosis	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Rosellinia bunodes (Berk. & Broome)Sacc. Rosellinia root rot	JP	a	C.M.I., 1972a; Knorr, 1965; Stevenson, 1975
Rosellinia necatrix Prill. White root rot	JP CA	a f	Anonymous, 1966; C.M.I., 1972b
Schizothyrium pomi (Mont & Fr.) Arx (Syn.: *Leptothyrium pomi* Sacc.) Flyspeck	JP AZ CA FL LA TX OT	c f	Anonymous, 1966; Whiteside, *et al.*, 1988
Sclerotinia sclerotiorum (Lib.) de Bary Sclerotinia twig blight (Cottony rot)	JP AZ CA FL TX OT	c f	Anonymous, 1966; Reuther, *et al.*, 1978; Whiteside, *et al.*, 1988
Sclerotium rolfsii Sacc. (Anamorph: *Corticium rolfsii* Curzi) Sclerotium rot	JP AZ CA FL LA TX OT	c f	C.M.I., 1974b; Fawcett, 1936
Septobasidium pseudopedicellatum Burt Felt	JP AZ CA FL LA TX OT	a b f	Anonymous, 1966; Whiteside, *et al.*, 1988

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Sporobolomyces roseus Kluyver & Niel Pseudo greasy spot	JP AZ CA FL TX OT	a f	Koziumi, 1986a; Whiteside, *et al.*, 1988
Bacteria			
Agrobacterium tumefaciens (Smith & Town.) Conn Crown gall	JP AZ CA FL LA TX OT	a c f	Bradbury, 1986
Citrus greening bacterium	JP	z	Miyakawa & Tsuno, 1989; Podleckis, 1995a; Whiteside, *et al.*, 1988
Pseudomonas syringae pv. *syringae* van Hall Black pit (Blast)	JP AZ CA FL LA TX OT	c f	Bradbury, 1986; Knorr, 1965
Xanthomonas campestris pv. *citri* (Hasse) Dye Citrus canker	JP	g w x z	Anonymous, 1966; Koziumi, 1981; Kuhara, 1978; Podleckis, 1995b; Whiteside, *et al.*, 1988
Virus and viruslike agents			
Citrus exocortis viroid	JP CA FL LA TX	d f	Tanaka, 1971; Whiteside, *et al.*, 1988
Citrus mosaic virus (=strain of Satsuma dwarf virus)	JP	d	Anonymous, 1966; Tanaka, 1971; Usugi & Saito, 1979; Whiteside, *et al.*, 1988
Citrus tristeza virus (Stem pitting disease)	JP AZ CA FL TX	a d f	Koziumi, 1986b; Kuhara, 1978; Whiteside, *et al.*, 1988
Citrus vein enation virus	JP CA	a f	Koziumi, 1986b; Whiteside, *et al.*, 1988
Citrus yellow mottle agent	JP	a d	Ushiyama, *et al.*, 1984; Whiteside, *et al.*, 1988

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Hassaku dwarf virus (=strain of Citrus tristeza virus)	JP	a d	Anonymous, 1966; Tanaka, 1971; Whiteside, *et al.*, 1988
Hop stunt viroid (=Citrus viroid IIA) (=Mild exocortis)	JP AZ CA FL	d f	Sano, *et al.*, 1986; Shikata, 1990
Natsudaidai dwarf virus (=strain of Satsuma dwarf virus)	JP	a d	Tanaka, 1971; Usugi & Saito, 1979; Whiteside, *et al.*, 1988
Navel orange infectious mottling virus (=strain of Satsuma dwarf virus)	JP	a d	Tanaka, 1971; Usugi & Saito, 1979; Whiteside, *et al.*, 1988
Psorosis	JP CA FL TX	a f	C.M.I., 1984; Whiteside, *et al.*, 1988
Satsuma dwarf virus	JP	a d	Anonymous, 1966; Tanaka, 1971; Usugi & Saito, 1979; Whiteside, *et al.*, 1988
Tatter leaf-citrange stunt virus (=Bud union crease)	JP CA FL	a d f	Miyakawa, 1980; Whiteside, *et al.*, 1988
Unknown etiology			
Bark rot	JP	a	Batchelor & Webber, 1948; Knorr, 1965
Nematodes			
Tylenchus semipenetrans Cobb Citrus nematode	JP AZ CA FL LA TX	a f	Anonymous, 1966; Whiteside, *et al.*, 1988

Table 2. Pest List, Japanese Unshu Oranges: Arthropods

Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Acallurothrips noguchii Kurosawa (Thysanoptera: Thripidae)	JP	a	Syoziro et al., 1965
Actenicerus orientalis Candeze (Coleoptera: Elateridae)	JP	a	Miwa, 1934
Aculops pelekassi (Keifer) (ACARI: Eriophyidae)	JP FL	f z	Seki,1979; Denmark, 1962, Rosen *et al.* 1994
Adoretus tenuimaculatus Waterhouse (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Adoxophyes orana fasciata Walsingham (Lepidoptera: Tortricidae)	JP	a g	Shiraki, 1952
Agrilus auriventris E. Saunders (Coleoptera: Buprestidae)	JP	a	Shiraki, 1952
Agriotes sericeus (Candeze) (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Agrius convolvuli (L.) (Lepidoptera: Spingidae)	JP	a g	Shiraki, 1952
Agrotis segetum (Schiffermuller) (Lepidoptera: Noctuidae)	JP	a g	Poole, 1989
Agrypnus binodulus Motschulsky (Coleoptera: Elateridae)	JP	a g	Shiraki, 1952
Alcides trifidus Pascoe (Coleoptera: Curculionidae)	JP	a	Shiraki, 1952
Alcis acaciaris Boisduval (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Aleurocanthus woglumi Ashby (Homoptera: Aleyrodidae)	JP FL TX	a f g	Metcalf & Metcalf 1993
Aleurocanthus spiniferus (Quaintance) (Homoptera: Aleyrodidae)	JP	a g	Shiraki, 1952
Aleurolobus marlatti Quaintance (Homoptera: Aleyrodidae)	JP	a g	Syoziro et al., 1965
Aleutuberculatus aucubae Kuwana (Homoptera: Aleyrodidae)	JP	a g	Diseases and Insect Pests of Fruit Trees. V. 1. Citrus, Loquat and Kiwifruit, 1992
Amata germana mandarina Butler (Lepidoptera: Amatidae)	JP	a	Shiraki, 1952
Anacanthocoris concoloratus Uhler (Hemiptera: Coreidae)	JP	a	Syoziro et al., 1965
Anacanthocoris striicornis Scott (Hemiptera: Coreidae)	JP	a	Syoziro et al., 1965
Anomala albopilosa Hope (Coleoptera: Scarabaeidae)	JP	a g	Shiraki, 1952
Anomala cuprea Hope (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952

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Anomala orientalis Waterhouse (Coleoptera: Scarabaeidae)	JP OT	a c f	Metcalf & Metcalf 1993
Anoplophora chinensis Foerster (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Anoplophora malasiaca Thomson (Coleoptera: Cerambycidae)	JP	a	List of Important Diseases and Pests of Economic Plants in Japan, 1966
Aonidiella aurantii Maskell (Homoptera: Diaspididae)	JP AZ FL TX CA	c f	Nakahara, 1982; Metcalf & Metcalf 1993
Aonidiella citrina Coquillet (Homoptera: Diaspididae)	JP FL CA	c f	Nakahara, 1982; Metcalf & Metcalf 1993
Apamea aquila Donzel (Lepidoptera: Noctuidae)	JP	a	Poole, 1989;
Aphis citricola van der Goot (Homoptera: Aphididae)	JP AZ FL TX	a c f	AZ Dept. of Agric., personal communication; Metcalf & Metcalf, 1993; Brown et al., 1988; Blackman & Eastop, 1985
Aphis gossypii Glover (Homoptera: Aphididae)	JP AZ FL TX OT	a c f	Metcalf & Metcalf 1993; Blackman & Eastop, 1985; AZ Dept. of Agric., personal communication
Apriona japonica Thomson (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Araecerus fasciculatus DeGeer (Coleoptera: Anthribidae)	JP FL OT TX	c	V. French, personal communication
Archips breviplicana (Walsingham) (Lepidopt.:Tortricidae)	JP	a	Shiraki, 1952
Archips ingentana Christopher (Lepidoptera: Tortricidae)	JP	a	Shiraki, 1952
Archips podana (Scopoli) (Lepidoptera: Tortricidae)	JP	a	Shiraki, 1952
Archips xylosteana L. (Lepidoptera: Tortricidae)	JP	a	Shiraki, 1952
Ascotis selenaria (D. & S.) (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Aspidiotus nerii Bouché (Homoptera: Diaspididae)	JP AZ CA FL LA TX OT	c f	Nakahara, 1982
Aspidiotus destructor Signoret (Homoptera: Diaspididae)	JP FL OT	c f	Nakahara, 1982
Asura dharma Moore (Lepidoptera: Arctiidae)	JP	a	Shiraki, 1952

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Athemus suturellus Motschulsky (Coleoptera: Cantharidae)	JP	b c	Shiraki, 1952
Athemus vitellinus Kiesenwetter (Coleoptera: Cantharidae)	JP	b c	Shiraki, 1952
Atractomorpha bedeli Bolivar (Orthoptera: Pyrogomorphidae)	JP	a	Syoziro et al., 1965
Atuphora stictica Matsumura (Homoptera: Cercopidae)	JP	a	Syoziro et al., 1965
Aulacorthum magnoliae Essig & Kuwana (Homoptera: Aphididae)	JP	a	Blackman & Eastop, 1985; Syoziro et al., 1965
Bactrocera cucurbitae (Diptera: Tephritidae)	JP(eradicated)	eradicated	EPPO 94/220
Bactrocera dorsalis (Hendel) (Diptera: Tephritidae)	JP(eradicated)	eradicated	EPPO
Bactrocera tsuneonis Miyake (Diptera: Tephritidae)	JP	z	INKTO
Bemisia afer Preisner & Hosny (Homoptera: Aleyrodidae)	JP	a	Nakahara, personal communication
Bemisia giffardi (Kotinsky) (Homoptera: Aleyrodidae)	JP	a	Nakahara, personal communication
Blenina senex Butler (Lepidoptera: Noctuidae)	JP	a	Poole, 1989; Shiraki, 1952
Brevipalpus lewisi McG. (Acari: Tenuipalpidae)	JP AZ CA OT	c f	Seizo, 1966
Brevipalpus obovatus Donnadieu (Acari: Tenuipalpidae)	JP AZ CA FL LA TX OT	c f	Jeppson et al., 1975
Callirhopalus bifasciatus (Roelofs) (Coleoptera: Curculionidae)	JP OT	c f	Shiraki, 1952
Cardiophorus vulgaris Motschulsky (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Ceroplastes floridensis Comstock (Homoptera: Coccidae)	JP FL LA TX	c f	Shiraki, 1952; Hamon and Williams, 1984
Ceroplastes rubens Maskell (Homoptera: Coccidae)	JP FL	f g	Syoziro et al., 1965
Ceroplastes rusci (L.) (Homoptera: Coccidae)	JP FL	a g	C. Riehard, personal communication
Ceroplastes ceriferus Fabricius (Homoptera: Coccidae)	JP	a	Syoziro et al., 1965
Ceroplastes pseudoceriferus Green (Homoptera: Coccidae)	JP	a	Syoziro et al., 1965
Ceroplastes japonicus Green (Homoptera: Coccidae)	JP	a	Syoziro et al., 1965

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Cetonia pilifera Motschulsky (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Chalioides kondonis Kondo (Lepidoptera: Psychidae)	JP	a	Shiraki, 1952
Chlorophorus annularis (Fabricius) (Coleoptera: Cerambycidae)	JP	a g	Shiraki, 1952; Duffy, 1968
Chrysochroa fulgidissima Schonherr (Coleoptera: Buprestidae)	JP	a	Shiraki, 1952
Chrysomphalus aonidum (L.) (Homoptera: Diaspididae)	JP FL TX	c f	Nakahara, 1982
Chrysomphalus bifasciculatus Ferris (Homoptera: Diaspididae)	JP CA LA TX OT	c f	Nakahara, 1982; Syoziro et al., 1965
Chrysomphalus dictyospermi (Morgan) (Homoptera: Diaspididae)	JP AZ FL TX	c f	AZ Dept. of Agric., personal communication; Nakahara, 1982
Clania minuscula Butler (Lepidoptera: Psychidae)	JP	a	Shiraki, 1952
Clania formosicola Strand (Lepidoptera: Psychidae)	JP	a	Shiraki, 1952
Coccus pseudomagnoliarum Kuwana (Homoptera: Coccidae)	JP CA	c f	Syoziro et al., 1965
Coccus hesperidum L. (Homoptera: Coccidae)	JP AZ CA FL TX	c f	AZ Dept. of Agric., personal communication; Gill, 1988; Syoziro et al., 1965
Coccus viridis (Green) (Homoptera: Coccidae)	JP FL	a g	Kawai, 1980
Coccus longulus (Douglas) (Homoptera: Coccidae)	JP FL CA	c f	Kawai, 1980
Conogethes punctiferalis (Guenee) (Lepidoptera: Pyralidae)	JP	a g	Shiraki, 1952
Contarinia okadai (Miyoshi) (Diptera: Cecidomyiidae)	JP	a	Shiraki, 1952
Corymbitodes gratus Lewis (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Crematogaster laboriosa Smith (Hymenoptera: Formicidae)	JP	a	Syoziro et al., 1965
Cryptothelea japonica Heylaerts (Lepidoptera: Psychidae)	JP	a	Shiraki, 1952
Dialeurodes kirkaldyi (Kotinsky) (Homoptera: Aleyrodidae)	JP FL TX	a c f	Nakahara, personal communication
Dialeurodes citri Ashmead (Homoptera: Aleyrodidae)	JP CA FL TX LA	a c f	Syoziro et al., 1965

Table 2. Pest List, Japanese Unshu Oranges: Arthropods

Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Diaphorina citri Kuway (Homoptera: Psyllidae)	JP	y	EPPO, 1992
Drosicha howardi (Homoptera: Margarodidae)	JP	a	Kawai, 1980
Drosicha corpulenta Kuwana (Homoptera: Margarodidae)	JP	a	Kawai, 1980
Dysgonia arctotaenia Gueneé (Lepidoptera: Noctuidae)	JP	e	Shiraki, 1952; Poole, 1989
Ectinohoplia obducta Motschulsky (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Ectropis cretacea Butler (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Ectropis excellens Butler (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Empoasca flavescens Fabricius (Homoptera: Cicadellidae)	JP	e	Syoziro et al., 1965; Takagi, 1981
Empoasca formosana (Homoptera: Cicadellidae)	JP	e	Korenaga, et al., 1992; Takagi, 1981
Empoasca sakaii (Homoptera: Cicadellidae)	JP	e	Korenaga, et al., 1992; Takagi, 1981
Eotetranychus asiaticus Ehara (Acari: Tetranychidae)	JP	z	Ehara, 1969
Eotetranychus kankitus Ehara (Acari: Tetranychidae)	JP	z	Jeppson *et al.* 1975
Epiacanthus stramineus Motschulsky (Homoptera: Errhomenellidae)	JP	a	Syoziro et al., 1965
Epuraea domina Reitter (Coleoptera: Nitidulidae)	JP	b c	Nakane 35 al., 1963
Erthesina fullo Thunberg (Hemiptera: Pentatomidae)	JP	a g	Syoziro et al., 1965
Eudocima amurensis Staudinger (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Eudocima fullonia (Clerck) (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Eupithecia carearia Leech (Lepidoptera: Geometridae)	JP	a g	Shiraki, 1952
Eupithecia signigera Butler (Lepidoptera: Geometridae)	JP	a	Inoue et al., 1959
Euproctis pulverea (Leech) (Lepidoptera: Lymantriidae)	JP	a	Shiraki, 1952
Euproctis similis (Fuessly) (Lepidoptera: Lymantriidae)	JP	a	Seizo, 1966; Ferguson, 1978
Exocentrus lineatus Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952

Table 2. Pest List, Japanese Unshu Oranges: Arthropods

Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments[2]	References
Fiorinia theae Green (Homoptera: Diaspididae)	JP FL TX OT	c f	Nakahara, 1982
Formica japonica Motschulsky (Hymenoptera: Formicidae)	JP	c	Syoziro et al., 1965
Frankliniella intonsa Brybom (Thysanoptera: Thripidae)	JP OT	a	Miyazaki and Kudo, 1988
Gampsocleis buergeri de Hann (Orthoptera: Tettigoniidae)	JP	a	Syoziro et al., 1965
Gargara genistae Fabricius (Homoptera: Membracidae)	JP OT	a	Syoziro et al., 1965
Gastrimargus transversus Thunberg (Orthoptera: Acrididae)	JP	a	Shiraki, 1952
Geisha distinctissima Walker (Homoptera: Flatidae)	JP	a i	Syoziro et al., 1965
Geococus citrinus Kuwana (Homoptera: Pseudococcidae)	JP	a	Shiraki, 1952
Gergithus variabilis Butler (Homoptera: Issidae)	JP	a	Syoziro et al., 1965
Glaucias subpuntatus Walker (Hemiptera: Pentatomidae)	JP	a	Syoziro et al., 1965
Glycyphana fulvistemma Motschulsky (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Halyomorpha picus Fabricius (Hemiptera: Pentatomidae)	JP	a	Shiraki, 1952
Haplothrips chinensis Priesner (Thysanoptera: Phlaeothripidae)	JP	a	Miyazaki and Kudo, 1987
Haplothrips subtissimus Haliday (Thysanoptera: Phlaeothripidae)	JP	a c	Miyazaki and Kudo, 1988
Helicoverpa armigera Hübner (Lepidoptera: Noctuidae)	JP	a	PNKTO; Poole, 1989; Shiraki, 1952
Heliothrips haemorrhoidalis Bouche (Thysanoptera: Thripidae)	JP AZ? FL TX CA LA OT	a c	AZ Dept. of Agric., personal communication; Syoziro et al., 1965
Hemerophila conjunctaria Leech (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Hemiberlesia lataniae (Signoret) (Homoptera: Diaspididae)	JP AZ FL	c	Nakahara, 1982
Hemithia aestivaria Hübner (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Hishimonus sellatus Uhler (Homoptera: Deltocephalidae)	JP	a	Syoziro et al., 1965
Holochlora longifissa Shiraki (Orthoptera: Tettigoniidae)	JP	a	Syoziro et al., 1965

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Holochlora japonica Brunner von Wattenwyl (Orthoptera: Tettigoniidae)	JP	a	Syoziro et al., 1965
Homona magnanima Diakonoff (Lepidoptera: Tortricidae)	JP	a	List of Important Diseases and Pests of Economic Plants in Japan, 1966
Homona coffearia Nietner (Lepidoptera: Tortricidae)	JP	a	Shiraki, 1952
Hoplia communis Waterhouse (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Icerya aegyptiaca (Douglas) (Homoptera: Margarodidae)	JP	a	Kawai, 1980
Icerya purchasi Maskell (Homoptera: Margarodidae)	JP AZ CA FL LA TX OT	a c	Syoziro et al., 1965
Icerya seychellarum (Westwood) (Homoptera: Margarodidae)	JP	a	Syoziro et al., 1965
Ishidaella albomarginata Signoret (Homoptera: Tettigellidae)	JP	a	Shiraki, 1952
Lacon binodulus (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Ledra auditura Walker (Homoptera: Ledridae)	JP	a	Syoziro et al., 1965
Lepidosaphes beckii (Newman) (Homoptera: Diaspididae)	JP CA FL LA OT TX	a c	Nakahara, 1982
Lepidosaphes camelliae Hoke (Homoptera: Diaspididae)	JP CA FL LA TX OT	c	Nakahara, 1982
Lepidosaphes gloveri (Packard) (Homoptera: Diaspididae)	JP CA FL TX LA OT	c	Nakahara, 1982
Lepidosaphes ulmi (L.) (Homoptera: Diaspididae)	JP AZ? CA FL TX LA OT	a c	AZ Dept. of Agric., personal communication; Nakahara, 1982
Leptocorisa varicornis Fabricius (Hemiptera: Coreidae)	JP	a	Shiraki, 1952
Lopholeucaspis japonica Cockerell (Homoptera: Diaspididae)	JP OT	a c	Nakahara, 1982
Luperodes pallidulus Baly (Coleoptera: Chrysomelidae)	JP	a	Shiraki, 1952
Luperodes moori Baly (Coleoptera: Chrysomelidae)	JP	a	Shiraki, 1952

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Luxiaria contigaria Walker (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Machaerotypus sibiricus Lethierry (Homoptera: Membracidae)	JP	a	Syoziro et al., 1965
Macrosiphum euphorbiae (Thomas) (Homoptera: Aphididae)	JP AZ CA FL LA TX OT	a c	Blackman & Eastop, 1985; Syoziro et al., 1965
Maenas salaminea Fabricius (Lepidoptera: Noctuidae)	JP	a	Poole, 1989; Shiraki, 1952
Malachius xantholoma Kiesenwetter (Coleoptera: Melyridae)	JP	b c	Shiraki, 1952
Maladera orientalis Motschulsky (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Martyrhilda culicitella(Herrich-Schaeffer) (Lepidopt.:Oecophoridae)	JP	a	Shiraki, 1952
Megalurothrips distalis Karny (Thysanoptera: Thripidae)	JP	a	Miyazaki and Kudo, 1988; Nakahara, personal communication
Melanotus annosus Candeze (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Mesopora onukii Matsumura (Homoptera: Tropiduchidae)	JP	a	Syoziro et al., 1965
Mesosa perplexa Pascoe (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952; Duffy, 1968
Mesosa longipennis Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Mesosa japonica Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Mimela flavilabris Waterhouse (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Monema flavescens Walker (Lepidoptera: Limacodidae)	JP	a	Shiraki, 1952
Monochamus subfasciatus Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Nezara antennata Scott (Hemiptera: Pentatomidae)	JP	a g	Syoziro et al., 1965
Nipponovalgus angusticollis Waterhouse (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Nodina chalcosoma Baly (Coleoptera: Chrysomelidae)	JP	a	Shiraki, 1952
Obiphora intermedia Uhler (Homoptera: Cercopidae)	JP	a	Syoziro et al., 1965

Table 2. Pest List, Japanese Unshu Oranges: Arthropods

Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Oliarus subnubilis Uhler (Homoptera: Cixiidae)	JP	a	Syoziro et al., 1965
Oliarus quadricinctus Matsumura (Homoptera: Cixiidae)	JP	a	Syoziro et al., 1965
Ophiusa coronata F. (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Ophthamodes i. irrorataria Bremer & Grey (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952
Oraesia emarginata (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Oraesia excavata (Butler) (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Orchamoplatus mammaeferus (Quaintance & Baker) (Homoptera: Aleyrodidae)	JP	a g	Russell, 1958
Orientus ishidae Matsumura (Homoptera: Deltocephalidae)	JP OT	a	Syoziro et al., 1965
Ornebius kanetaki Matsumura (Orthoptera: Gryllidae)	JP	e	Syoziro et al., 1965
Orthobelus flavipes Uhler (Homoptera: Membracidae)	JP	a	Syoziro et al., 1965
Othreis tyrannus Gueneé (Lepidoptera: Noctuidae)	JP	a	Shiraki, 1952; Poole, 1989;
Oxycetonia jucunda Faldermann (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Pandemis cerasana (Hübner) (Lepidoptera: Tortricidae)	JP	a	Inoue et al., 1959
Panonychus citri (McGregor) (Acari: Tetranychidae)	JP AZ CA FL LA TX OT	c f x	List of Important Diseases and Pests of Economic Plants in Japan, 1966
Panonychus ulmi (Koch) (Acari: Tetranychidae)	JP CA FL LA TX OT	c f	List of Important Diseases and Pests of Economic Plants in Japan, 1966
Papilio xuthus L. (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952
Papilio bianor dehaanii C. & R. Felder (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952
Papilio polytes polycles Fruhstorfer (Lepidoptera: Papilionidae)	JP	a	Inoue et al., 1959
Papilio protenor Cramer (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952
Papilio memnon thunbergi Siebold (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Papilio maackii tutanus Fenton (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952
Papilio helenus nicconicolens Butler (Lepidoptera: Papilionidae)	JP	a	Shiraki, 1952
Parabemisia myricae (Kuwana) (Homoptera: Aleyrodidae)	JP AZ CA FL	a g	AZ Dept. of Agric., personal communication
Parasa consocia (Cramer) (Lepidoptera: Limacodidae)	JP	a	Shiraki, 1952
Parasaissetia nigra (Nietner) (Homoptera: Coccidae)	JP CA FL LA TX	a c	Ben-Dov, 1993; Gill, 1988
Parlatoria cinerea Hadden (Homoptera: Diaspididae)	JP	z	Kawai, 1980
Parlatoria pergandii Comstock (Homoptera: Diaspididae)	JP CA FL TX	c f	Nakahara, 1982; Syoziro et al., 1965
Parlatoria proteus (Curtis) (Homoptera: Diaspididae)	JP FL OT TX	a c	Nakahara, 1982; Syoziro et al., 1965
Parlatoria theae Cockerell (Homoptera: Diaspididae)	JP TX OT	a c	Nakahara, 1982
Parlatoria ziziphi (Lucas) (Homoptera: Diaspididae)	JP FL	z	PNKTO No. 44; intro 1986
Patanga japonica Bolivar (Orthoptera: Acrididae)	JP	a	Syoziro et al., 1965
Penthimia nitidia Walker (Homoptera: Penthimiidae)	JP	a	Syoziro et al., 1965
Petalocephala discolor (Homoptera: Cicadellidae)	JP	a	Syoziro et al., 1965
Philsamia pryeri Butler (Lepidoptera: Saturniidae)	JP	a	Shiraki, 1952
Phloeobius gigas Fabricius (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Phyllocnistis citrella Stainton (Lepidoptera: Gracillariidae)	JP FL LA TX	a g	Shiraki, 1952
Phyllopertha irregularis Waterhouse (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Physopelta gutta Burmeister (Hemiptera: Largidae)	JP	a	Syoziro et al., 1965
Pinnaspis aspidistrae Signoret (Homoptera: Diaspididae)	JP AZ CA FL LA TX OT	a c	AZ Dept. of Agric., personal communication; Nakahara, 1982
Pinnaspis strachani Cooley (Homoptera: Diaspididae)	JP FL LA TX OT	a c	Nakahara, 1982
Planococcus citri Risso (Homoptera:Pseudococcidae)	JP AZ CA FL LA OT TX	c	AZ Dept. of Agric., personal communication

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Planococcus sp. immatures (Homoptera:Pseudococcidae)	JP	x	
Planococcus kraunhiae Kuwana (Homoptera: Pseudococcidae)	JP	z x	Shiraki, 1952
Planococcus lilacinus (Cockerell) (Homoptera: Pseudococcidae)	JP	z	Kawai, 1980
Plautia stali Scott (Hemiptera: Pentatomidae)	JP	a	Shiraki, 1952
Polyphagotarsonemus latus (Banks) (Acari: Tarsonemidae)	JP FL TX	c	Diseases and Insect Pests of Fruit Trees. V. 1. Citrus, Loquat and Kiwifruit, 1992
Polyrachis dives Smith (Hymenoptera: Formicidae)	JP	a b c	Shiraki, 1952
Polyrachis lamellidens Smith (Hymenoptera: Formicidae)	JP	a b c	Syoziro et al., 1965
Potosia aerata Erichson (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Protaetia brevitarsis Lewis (Coleoptera: Scarabaeidae)	JP	a	Shiraki, 1952
Pseudocalamobius japonicus Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Pseudaonidia duplex (Cockerell) (Homoptera: Diaspididae)	JP FL LA TX OT	c	Nakahara, 1982
Pseudaonidia trilobitiformis Green (Homoptera: Diaspididae)	JP FL	a f	NPAG
Pseudococcus comstocki Kuwana (Homoptera: Pseudococcidae)	JP CA FL LA OT	c	Shiraki, 1952
Pseudococcus cryptus (citriculus) Hempl (Homoptera: Pseudococcidae)	JP	z	Avidov and Harpaz, 1969
Pseudococcus sp. (undescribed) (Homoptera: Pseudococcidae)	JP	z x	
Pseudococcidae, sp. of, immatures (Homoptera)	JP	x	
Psorosticra melanocrepida Clarke (Lepidoptera: Tortricidae)	JP	a	Inoue et al., 1959
Psylla coccinea (Homoptera: Psyllidae)	JP	a	Syoziro et al., 1965
Pterolophia caudata Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Pterolophia jugosa (Bates) (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Pterolophia leiopodina Bates (Coleoptera: Cerambycidae)	JP	a	Nakane et al., 1963

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Pterolophia zonata Bates (Coleoptera: Cerambycidae)	JP	a	Shiraki, 1952
Pulvinaria aurantii Cockerell & Rob (Homoptera: Coccidae)	JP	a	Ben-Dov, 1993
Pulvinaria citricola Kuwana (Homoptera: Coccidae)	JP CA? OT	a	Ben-Dov, 1993; Gill, 1988
Pulvinaria okitsuensis Kuwana (Homoptera: Coccidae)	JP	a	Ben-Dov, 1993
Pulvinaria psidii Maskell (Homoptera: Coccidae)	JP CA FL OT	a	Ben-Dov, 1993
Pyramidotettix citri (Matsumura) (Homoptera: Cicadellidae)	JP	a	Shiraki, 1952
Quadraspidiotus perniciosus Comstock (Homoptera: Diaspididae)	JP AZ CA FL LA TX OT	c	Nakahara, 1982; Metcalf & Metcalf 1993
Rhizoecus kondonis Kuwana (Homoptera: Pseudococcidae)	JP CA	a	Hambleton, 1976
Rhopalosiphum maidis (Fitch) (Homoptera: Aphididae)	JP AZ CA FL LA TX OT	c	Metcalf & Metcalf 1993; Blackman & Eastop, 1985
Ricania japonica Melichar (Homoptera: Ricaniidae)	JP	a	Syoziro et al., 1965
Saissetia citricola (Homoptera: Coccidae)	JP	a	Syoziro et al., 1965
Scepticus griseus Roelofs (Coleoptera: Curculionidae)	JP	a	Shiraki, 1952
Scepticus insularis Roelofs (Coleoptera: Curculionidae)	JP	a	Shiraki, 1952
Scirtothrips dorsalis Hood (Thysanoptera: Thripidae)	JP FL	a e g	Lab. Ent. J. 81; S. Nakahara, personal communication
Selatosomus notabilis Candeze (Coleoptera: Elateridae)	JP	a	Shiraki, 1952
Sinomegoura citricola van der Goot (Homoptera: Aphididae)	JP	a	Syoziro et al., 1965; Blackman & Eastop, 1985
Solenostethium chinense Stal (Hemiptera: Pentatomidae)	JP	a	Shiraki, 1952
Sphenophorus carinicollis Gyllenhal (Coleoptera: Curculionidae)	JP	a	Shiraki, 1952
Spilarctia inequalis inequalis Butler (Lepidoptera: Arctiidae)	JP	a	Shiraki, 1952

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae)	JP	a g	INKTO No. 25; Shiraki, 1952; Poole, 1989
Sujitettix ferrugineus Matsumura (Homoptera: Cicadellidae)	JP	a	Syoziro et al., 1965
Takahashia japonica Cockerell (Homoptera: Coccidae)	JP	a	Ben-Dov, 1993
Tartessus ferrugineus Walker (Homoptera: Tartessidae)	JP	a	Syoziro et al., 1965
Tettigella viridis L. (Homoptera: Tettigellidae)	JP	a	Syoziro et al., 1965
Tettigonia orientalis Uvarov (Orthoptera: Tettigoniidae)	JP	a	Syoziro et al., 1965
Tetranychus cinnabarinus (Boisduval) (Acari: Tetranychidae)	JP AZ CA FL LA OT TX	c	Jeppson *et al.* 1975
Tetranychus kanzawai Kishida (Acari: Tetranychidae)	JP	z	Yi-Hsiung, 1975
Thrips coloratus Schmutz (Thysanoptera: Thripidae)	JP	a	Nakahara, personal communication
Thrips flavus Schrank (Thysanoptera: Thripidae)	JP	a	Nakahara, personal communication
Thrips hawaiiensis Morgan (Thysanoptera: Thripidae)	JP CA FL OT TX	a	Nakahara, personal communication
Thrips tabaci Lind. (Thysanoptera: Thripidae)	JP AZ CA FL LA OT TX	a	Nakahara, personal communication
Thrips vitticornis (Karny) (Thysanoptera: Thripidae)	JP	a	Nakahara, personal communication
Thyas juno Dalman (Lepidoptera: Noctuidae)	JP	e	Poole, 1989; Shiraki, 1952
Toxoptera aurantii Boyer de Fonscolombe (Homoptera: Aphididae)	JP AZ FL TX CA OT	a	AZ Dept. of Agric., personal communication; Blackman & Eastop, 1985; Blackman & Eastop, 1985
Toxoptera citricidus Kirkaldy (Homoptera: Aphididae)	JP	y	PDS; Blackman & Eastop, 1985
Toxoptera odinae van der Goot (Homoptera: Aphididae)	JP	a	Blackman & Eastop, 1985
Unaspis euonymi Comstock (Homoptera: Diaspididae)	JP CA FL LA OT TX	a c	Nakahara, 1982
Unaspis yanonensis Kuwana (Homoptera: Diaspididae)	JP	z x	Kawai, 1980

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Arthropod Pests: *Genus species* Author (Order: Family)	Distribution[2]	Comments [2]	References
Valanga nigricornis (Burmeister) (Orthoptera: Pyrgomorphidae)	JP	a	Syoziro et el., 1965
Xanthochroa waterhousei Harold (Coleoptera: Oedemeridae)	JP	c	Shiraki, 1952
Xyleborus perforans (Wollaston) (Coleoptera: Scolytidae)	JP	a	Wood, 1992
Xyleborus saxensi (Ratzburg) (Coleoptera: Scolytidae)	JP AZ CA FL LA OT TX	a c	Wood, 1992
Xylena fumosa Butler (Lepidoptera: Noctuidae)	JP	a	Poole, 1989; Shiraki, 1952
Zamacra juglansiaria Graeser (Lepidoptera: Geometridae)	JP	a	Shiraki, 1952

[1] Scientific names of fungi and bacteria as listed in Anonymous, 1966; Bradbury,1986; and Farr, *et al.*,1989.

[2] Distribution legend: JP- Japan; AZ- Arizona; CA- California; FL- Florida; LA- Louisiana; TX- Texas; OT- Other, occurs in states other than AZ, CA, FL, LA, TX

[3] Comments:

a - Pest mainly associated with plant part other than commodity
b - Not likely to be a primary plant pest
c - Listed in U.S. Department of Agriculture (USDA) catalogue of pest interceptions as non-actionable
d - Commodity is unlikely to serve as inoculum source because vector is unknown or does not feed on commodity and/or seed transmission has not been reported in *Citrus* spp. (viruses)
e - Although pest attacks commodity, it would not be expected to remain with the fruit during processing
f - Pest occurs in the U.S. and is not currently subject to official restrictions and regulations (*i.e.*, not listed as actionable or non-actionable, and no official control program)
g - Listed in the USDA catalogue of intercepted pests as actionable
h - Pest is present in the U.S. and is listed in the USDA catalogue of intercepted pests as actionable at ports of entry, but, the pest is not currently subject to further official restrictions and regulations.
i - A single unconfirmed report lists this species (with no supporting evidence) as a vector of Satsuma Dwarf Virus (SDV), however, this species is not implicated as a vector in recent literature; the vector of SDV is believed to be soil borne.
w - Program pest
x - Multiple interception records exist
y - Pest is a vector of *Citrus* diseases
z - Pest is known to commonly attack or infect fruit and it would be reasonable to expect the pest may remain with the fruit during processing and shipping

This assumption eliminated many serious citrus pests from further consideration. For example, there are a variety of fruit-piercing moths (Noctuidae) in Japan; although these moths have a close association with the fruit — the adults feed on fruit — their large size and behavior makes it unlikely that individuals would remain on fruit during processing and packing. Another example of pests not analyzed further is arthropods that feed strictly on leaves; although these are serious pests, they do not normally attack the fruit and phytosanitary conditions required to satisfy existing statutes (*e.g.*, Quarantine 56) are sufficient to ensure that these pests do not accompany shipments of fruit.

B. Pests Selected for Further Analysis, Quarantine Pests

According to international guidelines (*e.g.*, United Nations Food and Agriculture Organization, FAO), quarantine pest is defined as: "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled". For consistency with international guidelines, we performed extended assessments only on pests that qualified as quarantine pests under this definition. Thus, pests selected for further analysis satisfied the following criteria:

1. The pest is of potential economic importance to citrus producing areas of the continental U.S.
2. The pest does not occur in the U.S., or, the pest has limited distribution in the U.S. and is being controlled officially
3. The species is known to be a pest of the commodity and not just the plant species
4. It would be reasonable to expect that the pest may remain with the fruit during processing

In addition to pests satisfying all three of the above criteria, two arthropod pests were also considered further. Although these two arthropods satisfy international guidelines as quarantine pests (criteria 1 and 2 above), they do not necessarily satisfy criteria 3 and 4. They were included on the list of pests to be analyzed further because they are important vectors of citrus diseases that occur in Japan but not in the U.S. Our list of pests selected for further analysis includes two pathogens and eleven arthropods:

- *Xanthomonas campestris* pv. *citri* - Citrus bacterial canker (pathogen)
- Citrus Greening Bacterium — pathogen
- *Eotetranychus kankitus* Ehara — mite
- *Eotetranychus asiaticus* Ehara — mite
- *Tetranychus kanzawai* Kishida — mite
- *Planococcus lilacinus* (Cockerell) — mealybug
- *Planococcus kraunhiae* Kuwana — mealybug
- *Pseudococcus cryptus* Hempl — mealybug
- *Parlatoria cinerea* Hadden — armored scale insect
- *Unaspis yanonensis* Kuwana — armored scale insect
- *Toxoptera citricida* Kirkaldy — aphid (vector of citrus tristeza and other viruses)
- *Diaphorina citri* Kuway — psyllid (vector of citrus greening bacterium)
- *Bactrocera tsuneonis* Miyake — tephritid fruit fly

Most pests listed in Table 2 were not analyzed further. Although many listed pests may be serious plant pests, there were a variety of reasons for not analyzing them further. The most common reasons were:

1. The pest occurs in the U.S. and there is no official Federal program for controlling the pest or regulating its interstate movement.
2. The pest is associated mainly with plant parts other than commodity (the plant part to be imported).

3. Although the pest may be associated with the commodity, we did not consider it reasonable to expect these pests would remain with the fruit during processing.
4. The pest is listed as non-actionable at U.S. ports of entry.

For example, there are a variety of fruit-piercing moths in Japan that attack citrus fruits. However, the probability that any life stage of these moths would remain with mature fruit during processing was considered to be quite low. Another example of serious pests of citrus that would not be expected to be associated with mature fruit (*e.g.*, *Anoplophora chinensis* Foerster (Coleoptera: Cerambycidae)).

State officials expressed concern about another group not selected for further analysis: thrips (Thysanoptera: Thripidae). Although Table 2 includes several species of thrips in our pest list, they are not analyzed further because we consider the likelihood that these species would remain with the fruit during harvest, post harvest processing, and shipment to be small. Additionally, thrips are generally detectable by inspection and all shipments of Japanese Unshu orange fruits are, and will continue to be subject to inspection. Finally, there are no records of thrips intercepted on commercial shipments of Unshu orange fruits from Japan.

III. Estimates of Pest Risk Potential, Selected Pests

We estimated a pest risk potential (PRP) for each of the 13 pests listed in the previous section as candidates for further analysis. For each risk element (see below) each pest is assigned a risk value of **high** (3 points), **medium** (2 points), **low** (1 point), or **not/none** (0 points) as indicated.

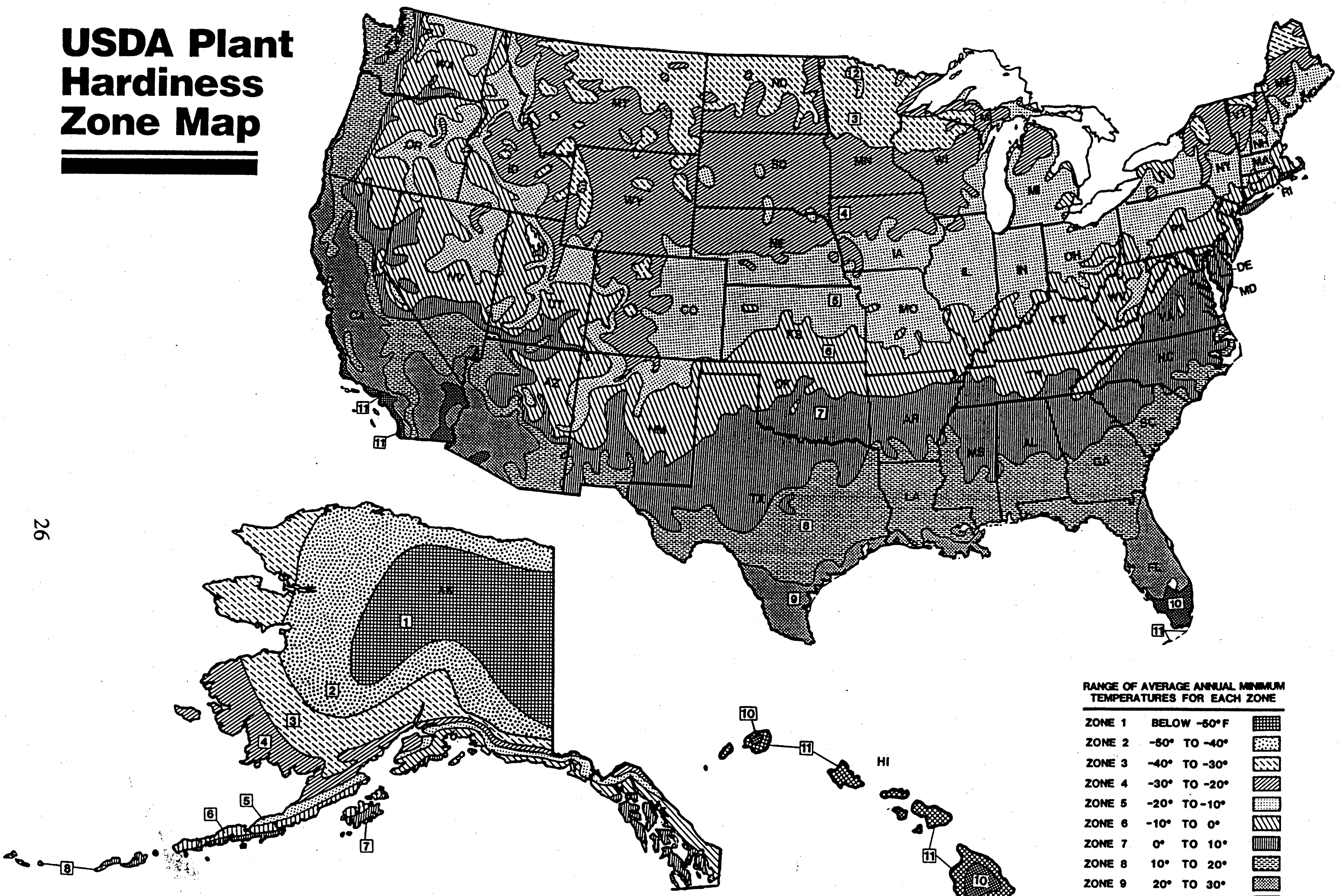
The lowest possible PRP is 3; pests with RP values of 3-6 are not considered to represent any significant risk, low risk pests have PRP values of 7-9, medium risk pests have PRP values of 10-12, and high risk pests have PRP values of 13-15. The PRP is considered to be a biological indicator of the potential destructiveness of the pest.

Risk Element #1: Climate—Host Interaction

Rationale: When a pest is introduced to a new area, if host plants are available and climatic conditions are similar to its native area, it can be expected to behave as it does in its native area. The evaluation will consider ecological zonation, interaction between the geographic distribution of the pest and geographic distribution of the host. For this element, risk values are based on the availability of both host material and suitable climate conditions. To rate this risk element, we use the U.S. "Plant Hardiness Zones" as described by the U.S. Department of Agriculture (see Figure 1) (Cathey, 1990). Risk values were assigned according to the following. Due to the availability of both suitable host plants and suitable climate, the pest has potential to establish a breeding colony:

High (3):	In four or more plant hardiness zones.
Medium (2):	In two or three plant hardiness zones.
Low (1):	In only a single plant hardiness zone.
None (0):	In none of the plant hardiness zones.

USDA Plant Hardiness Zone Map



RANGE OF AVERAGE ANNUAL MINIMUM TEMPERATURES FOR EACH ZONE	
ZONE 1	BELOW -50°F
ZONE 2	-50° TO -40°
ZONE 3	-40° TO -30°
ZONE 4	-30° TO -20°
ZONE 5	-20° TO -10°
ZONE 6	-10° TO 0°
ZONE 7	0° TO 10°
ZONE 8	10° TO 20°
ZONE 9	20° TO 30°
ZONE 10	30° TO 40°
ZONE 11	ABOVE 40°

The zones of plant hardiness in the United States—This map is an adaptation of the color map on the reverse side. It lacks many fine details of the color map but may be useful for small-scale reproduction in books, magazines, and nursery catalogs.

Figure 1

Risk Element #2: Host range

Rationale: The risk posed by a plant pest depends on both its ability to establish a viable reproductive population and its potential for causing plant damage. We assumed risk is correlated positively with host range. For pathogens, risk is more complex and depends on host range, aggressiveness, virulence and pathogenicity. For both arthropods and pathogens, we rated risk primarily as a function of host range as follows:

High (3):	Pest attacks multiple species within multiple plant families.
Medium (2):	Pest attacks multiple species within a single plant family.
Low (1):	Pest attacks only a single species or multiple species within a single genus.

Risk Element #3: Dispersal Potential

Rationale: A pest may disperse after establishment in a new area. The following items are considered:

- reproductive patterns in the pest (*e.g.*, voltinism, reproductive output)
- innate dispersal capability of the pest
- whether natural factors (*e.g.*, wind, water, presence of vectors) facilitate dispersal

High (3):	Pest has high reproductive potential (*e.g.*, multiple generations or cohorts per year, many offspring per reproductive event, high innate capacity of a population for increase (*i.e.*, the species is "r-selected"), ***AND*** individuals are highly mobile (*i.e.*, capable of moving long distances — at least 20 km — either under their own power, or by being moved by natural forces such as wind, water or vectors).
Medium (2):	Pest has either high reproductive potential ***OR*** the species is motile.
Low (1):	Neither high reproductive potential nor highly mobile.

Risk Element #4: Economic Impact

Rationale: Introduced pests are capable of causing a variety of economic impacts. We divide these impacts into three categories:

1. Lower yield of the host crop (*e.g.*, by causing plant mortality, or by acting as a disease vector)
2. Lower value of the commodity (*e.g.*, by increasing costs of production, lowering market price, or a combination)
3. Loss of markets (foreign or domestic).

High (3):	Pest causes all three types of impacts.
Medium (2):	Pest causes any two of the above impacts.
Low (1):	Pest causes any one of the above impacts.
None (0):	Pest does not cause any of the above impacts.

Risk Element #5: Environmental Impact

1. Establishment of the pest is expected to cause significant, direct environmental impacts (*e.g.*, ecological disruptions, reduced biodiversity, use of synthetic pesticides to control infestations of the pest).

2. Pest is expected to have direct impacts on species listed by Federal or State agencies as endangered, threatened, or candidate. An example of a direct impact would be feeding on a listed plant. If feeding trials with the pest have not been conducted on the listed organism (no direct negative data), a pest will be expected to feed on the plant if it feeds on other species within the genus or other genera within the family.
3. Pest is expected to have indirect impacts on species listed by Federal or State agencies as endangered, threatened, or candidate species (*e.g.*, by disrupting sensitive, critical habitat).
4. Establishment of the pest would stimulate control programs consisting of toxic chemical pesticides, or release of nonindigenous biological control agents.

High (3):	Two or more of the above.
Medium (2):	One of the above.
Low (1):	None of the above (it is assumed that establishment of a nonindigenous pest will have at least some environmental impact).

This information is displayed in tabular form with scores for each of the risk elements for each pest (Table 3). The risk potential of each pest is estimated by adding together the risk values (one for each risk element).

IV. Extended Assessment, Selected Pests

A. Scenario Analysis

After estimating pest risk potentials, we conducted extended assessments on any pest with an estimated risk potential of medium or high (*i.e.*, PRP's of 10 or greater). The estimated pest risk potential for only one of the pests selected for further analysis was estimated as low (*i.e.*, PRP in the range of 7-9). This pest (*i.e.*, Citrus Greening Bacterium) was not analyzed further. We did not conduct separate assessments on pests with similar biologies (*e.g.*, the two species of mites were treated together).

We conducted extended assessments on the following seven pests/pest categories:

Xanthomonas campestris pv. *citri*, Citrus Bacterial Canker
Mites (three species)
Mealybugs (three species)
Armored scale insects (two species)
Diaphorina citri
Toxoptera citricida
Bactrocera tsuneonis

All of these pests met international guidelines as quarantine pests and were considered to be of sufficient concern to warrant more detailed examination. Proposed program alternatives under consideration fall into two categories:

- Importation to all States, including citrus producing States
- Establishment of an official preclearance program.

Table 3. Risk estimates (see section III of text for descriptions of risk elements and assignment of risk values)

Pest	Climate/ Host Interaction	Host range	Dispersal Potential	Economic Impact	Environ-mental Impact	TOTAL (PRP)
Xanthomonas campestris pv. *citri*	3	2	2	3	2	12
Citrus Greening Bacterium	2	2	1	3	1	9
Eotetranychus asiaticus	3	3	2	2	1	11
Eotetranychus kankitus	3	3	2	2	1	11
Tetranychus kanzawai	3	3	2	2	1	11
Planococcus lilacinus	3	3	2	2	1	11
Planococcus kraunhiae	3	3	2	2	1	11
Pseudococcus cryptus	3	3	2	2	1	11
Parlatoria cinerea	3	3	2	2	2	12
Unaspis yanonensis	3	2	2	3	3	13
Toxoptera citricida	3	2	3	3	2	13
Diaphorina citri	3	2	3	3	2	13
Bactrocera tsuneonis	3	1	2	3	3	12

Thus, we considered the following four scenarios (Figure 2, p.31):

1. **No official preclearance, fruit allowed to current (non-citrus producing) States only**

   This is the current situation. In addition to orchard inspection, fruit are subjected to a chlorine dip for citrus bacterial canker, unofficial preclearance (inspection), voluntary methyl bromide treatment, and port of entry inspection.

2. **No official preclearance, fruit allowed into citrus-producing States**

   Current situation but with fruit going to citrus-producing States. Despite current mitigations, quarantine and other pests have been intercepted repeatedly in shipments of Unshu orange fruits from Japan.

3. **Official preclearance program, fruit allowed to current (non-citrus producing) States only**

   Preclearance would probably involve additional mitigations for quarantine pests.

4. **Official preclearance program, fruit allowed into citrus-producing States**

   Preclearance would probably involve additional mitigations for quarantine pests.

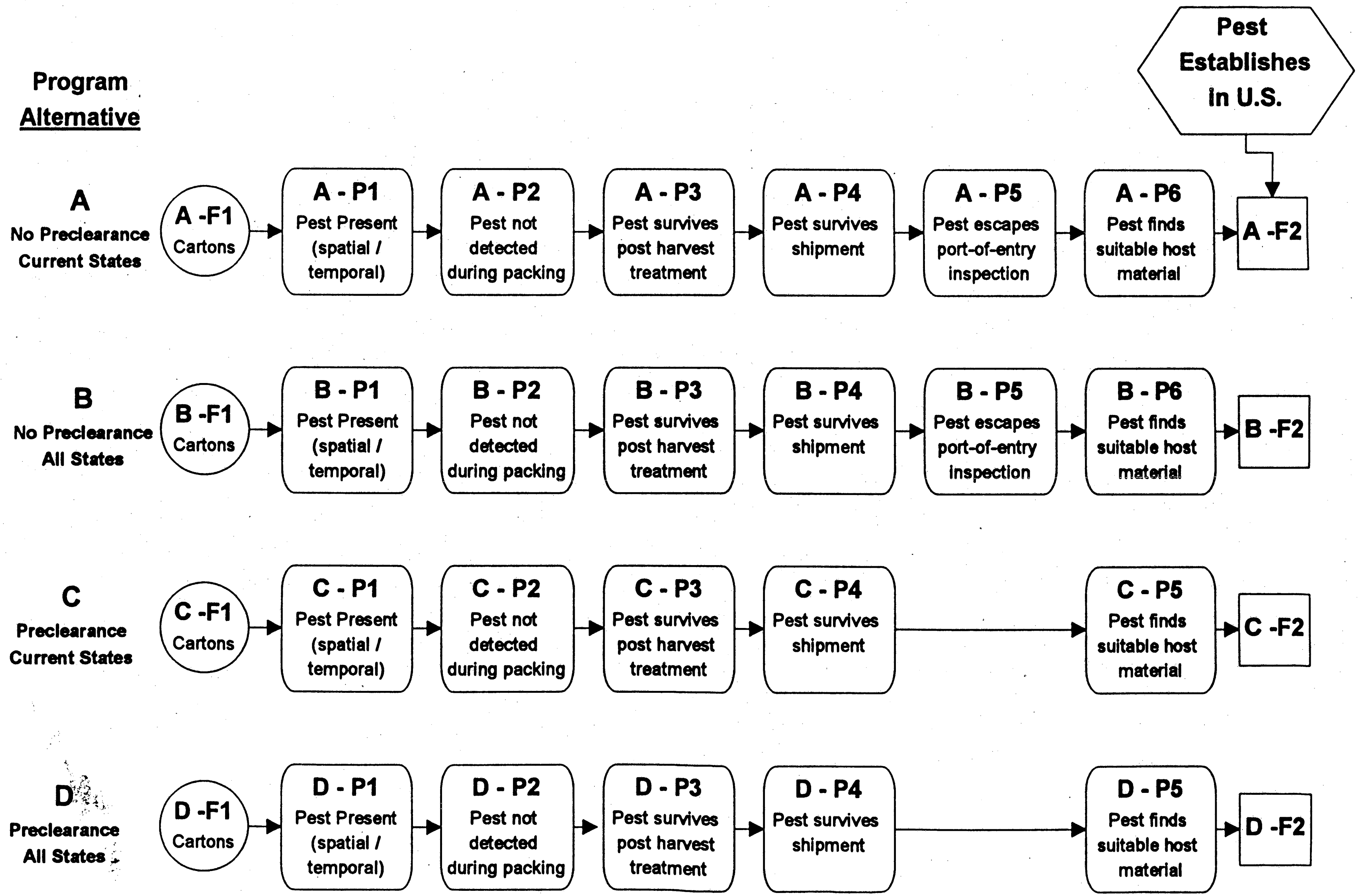
B. Monte Carlo Simulations

1. General

For each combination of program alternative and pest/pest category, we estimated probability of establishment using Monte Carlo simulations. The Monte Carlo simulations provided quantitative estimates of the likelihood of establishment of various pests under these four scenarios and constitute a quantitative risk assessment. We used the personal computer program *@Risk* for Excel (Palisade Corp., Newfield, NY, USA) to run our simulations. The extended assessment (*i.e.*, scenario analyses, Monte Carlo simulations, and management recommendations) for the three species of mites listed as quarantine pests is also appropriate for most or all of the other mites on the pest list. Similarly, the extended assessments for mealybugs and armored scale insects are appropriate for other mealybugs and armored scale insects on the pest list. We consider the extended assessment for *Diaphorina citri* to be appropriate for other Homopterans not already covered in another extended assessment. We consider the extended assessment for *Toxoptera citricida* to be appropriate for other aphids.

Several assumptions were made in arriving at the probability estimates used in the scenario trees constructed for *X. campestris* pv. *citri*. It was assumed that safeguards currently included in the Unshu orange comprehensive work plan administered by APHIS and MAFF would remain in place. These safeguards include, but are not restricted to, location of exporting groves in areas certified by MAFF and APHIS to be free of *X. campestris* pv. *citri*, planting of only canker-resistant varieties of citrus within the exporting area, planting of a buffer zone of canker-resistant citrus varieties around exporting groves, preharvest and harvest inspections of groves to ensure their freedom from citrus canker disease, harvest and post harvest inspections of packing house operations, a bactericidal dip for fruit at the packing house, proper labeling as to product, country of origin and phytosanitary declarations and, in Program Alternatives C and D- No Official Preclearance Program, inspection of the commodity at the port of entry.

Figure 2: Scenario Analysis, Pests of Japanese Unshu Orange



Except for *B. tsuneonis*, all Monte Carlo simulations assumed that Japan would be exporting Unshu orange fruit from anywhere in Japan. Currently, only Unshu orange fruits grown in areas reported to be free of *B. tsuneonis* are being exported to the U.S. *B. tsuneonis* is known to occur in certain parts of Japan, including areas on the island of Kyushu (this is the only arthropod pest for which we have such detailed information). Currently, Japan is not exporting Unshu orange fruits from Kyushu to the U.S. However, Japan has requested permission to bring Unshu orange fruit from Kyushu. Thus, we conducted two separate sets of Monte Carlo simulation for *B. tsuneonis*. One set of simulations covers exports of fruits grown in areas known to be free of *B. tsuneonis* (*e.g.*, the islands of Shikoku and Honshu, and the areas of Kyushu known to be free of *B. tsuneonis*). The other set of simulations covers fruit grown anywhere in Japan, including areas infested with *B. tsuneonis*. Thus, we report results from 32 separate Monte Carlo simulations.

2. Input Values and Justifications

Input values used in the Monte Carlo simulations are shown in Tables 4-11. Our estimates for the number (frequency) of cartons that would be imported on an annually were based on current and recent levels. During 1995, 78,400 cartons were imported (a carton is the unit typically placed on grocery shelves). Four cartons are bundled together for shipment into a master carton. Each shipping container holds 980 master cartons. During the already completed 1995 fiscal year shipping season (November 1994 through February 1995), 20 containers were shipped in two shiploads. Importation levels were down from recent maximum levels of 200,000 cartons per year. Thus, for scenarios under program alternative "A" (no official preclearance, fruit to current States only), we estimated minimum importation levels to be one shipload (40,000 cartons) and the maximum to be the recent maximum levels. These figures were doubled under scenarios allowing fruit to all U.S. States, and increased by 50% with official preclearance and current States. Our estimates were influenced by assuming that preclearance would be costlier to exporters but would entail less risk of refused shipments.

Input values for the probabilities used in the Monte Carlo simulations were based largely on expert judgment. A core team of three entomologists and three plant pathologists estimated probabilities in group sessions over several days. However, numerous technical specialists (*e.g.*, scientists specializing on particular taxonomic groups, port inspectors, specialists in international trade, inspectors recently involved in the Japanese Unshu orange export program, *etc.*) were consulted throughout the process regarding various details.

Estimates were derived at each node based on the following:

- Pest interception records on Unshu orange fruits in cargo
- General biology of pest group
- Judgement based on laboratory experience
- Judgement based on field experience
- Judgement based on inspection experience
- Pest association with export quality fruit being processed under the U.S. and Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) requirements

In some cases data were available which suggested particular values. Values at a particular node for the various pests were considered relative to each other.

Table 4. Summary data for scenario analysis / quantitative risk assessment.

Xanthomonas campestris pv. *citri* - Citrus Bacterial Canker				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
A - P_2 — not detected, packing	uniform	0.000001	-	0.0001
A - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
A - P_4 — survive shipment	uniform	0.5	-	0.9
A - P_5 — not detected at POE	uniform	0.000001	-	0.0001
A - P_6 — find host	uniform	0.0000000001	-	0.00000001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
B - P_2 — not detected, packing	uniform	0.000001	-	0.0001
B - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
B - P_4 — survive shipment	uniform	0.5	-	0.9
B - P_5 — not detected at POE	uniform	0.000001	-	0.0001
B - P_6 — find host	uniform	0.0000000001	-	0.00000001
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
C - P_2 — not detected, packing	uniform	0.0000001	-	0.00001
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.5	-	0.9
C - P_5 — find host	uniform	0.00000001	-	0.000001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
D - P_2 — not detected, packing	uniform	0.0000001	-	0.00001
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.5	-	0.9
D - P_5 — find host	uniform	0.00000001	-	0.000001

Table 5. Summary data for scenario analysis / quantitative risk assessment.

Mites (*e.g., Tetranychus kanzawi, Eotetranychus asiaticus*)				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.01
A - P_2 — not detected, packing	uniform	0.25	-	0.9
A - P_3 — survive post harvest	triangular	0.0001	0.01	0.25
A - P_4 — survive shipment	triangular	0.01	0.1	0.5
A - P_5 — not detected at POE	triangular	0.05	0.5	0.8
A - P_6 — find host	uniform	0.0001	-	0.001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.01
B - P_2 — not detected, packing	uniform	0.25	-	0.9
B - P_3 — survive post harvest	triangular	0.0001	0.01	0.25
B - P_4 — survive shipment	triangular	0.01	0.1	0.5
B - P_5 — not detected at POE	triangular	0.05	0.5	0.8
B - P_6 — find host	uniform	0.0001	-	0.001
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.01
C - P_2 — not detected, packing	uniform	0.25	-	0.9
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	triangular	0.01	0.1	0.5
C - P_5 — find host	uniform	0.001	-	0.01
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.01
D - P_2 — not detected, packing	uniform	0.25	-	0.9
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	triangular	0.01	0.1	0.5
D - P_5 — find host	uniform	0.001	-	0.01

Table 6. Summary data for scenario analysis / quantitative risk assessment.

Mealybugs (*e.g., Planococcus kraunhiae, Pseudococcus cryptus*)				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.65	-	0.95
A - P_2 — not detected, packing	uniform	0.25	-	0.9
A - P_3 — survive post harvest	triangular	0.001	0.01	0.1
A - P_4 — survive shipment	uniform	0.5	-	0.9
A - P_5 — not detected at POE	triangular	0.01	0.02	0.1
A - P_6 — find host	uniform	0.001	-	0.01
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.65	-	0.95
B - P_2 — not detected, packing	uniform	0.25	-	0.9
B - P_3 — survive post harvest	triangular	0.001	0.01	0.1
B - P_4 — survive shipment	uniform	0.5	-	0.9
B - P_5 — not detected at POE	triangular	0.01	0.02	0.1
B - P_6 — find host	uniform	0.001	-	0.01
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.65	-	0.95
C - P_2 — not detected, packing	uniform	0.25	-	0.9
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.5	-	0.9
C - P_5 — find host	uniform	0.001	-	0.01
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.65	-	0.95
D - P_2 — not detected, packing	uniform	0.25	-	0.9
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.5	-	0.9
D - P_5 — find host	uniform	0.001	0	0.01

Table 7. Summary data for scenario analysis / quantitative risk assessment.

Scale Insects (*e.g., Unaspis yanonensis, Parlatoria cinerea*)				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.01	-	0.1
A - P_2 — not detected, packing	uniform	0.05	-	0.25
A - P_3 — survive post harvest	triangular	0.001	0.05	0.25
A - P_4 — survive shipment	uniform	0.1	-	0.9
A - P_5 — not detected at POE	uniform	0.001	-	0.02
A - P_6 — find host	uniform	0.00001	-	0.0001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.01	-	0.1
B - P_2 — not detected, packing	uniform	0.05	-	0.25
B - P_3 — survive post harvest	triangular	0.001	0.05	0.25
B - P_4 — survive shipment	uniform	0.1	-	0.9
B - P_5 — not detected at POE	uniform	0.001	-	0.02
B - P_6 — find host	uniform	0.0001	-	0.01
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.01	-	0.1
C - P_2 — not detected, packing	uniform	0.001	-	0.01
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.1	-	0.9
C - P_5 — find host	uniform	0.00001	-	0.0001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.01	-	0.1
D - P_2 — not detected, packing	uniform	0.0001	-	0.01
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.1	-	0.9
D - P_5 — find host	uniform	0.0001	-	0.01

Table 8. Summary data for scenario analysis / quantitative risk assessment.

Diaphorina citri - Citrus psylla				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
A - P_2 — not detected, packing	uniform	0.01	-	0.1
A - P_3 — survive post harvest	uniform	0.0001	-	0.001
A - P_4 — survive shipment	uniform	0.1	-	0.5
A - P_5 — not detected at POE	uniform	0.0001	-	0.01
A - P_6 — find host	uniform	0.00001	-	0.0001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
B - P_2 — not detected, packing	uniform	0.01	-	0.1
B - P_3 — survive post harvest	uniform	0.0001	-	0.001
B - P_4 — survive shipment	uniform	0.1	-	0.5
B - P_5 — not detected at POE	uniform	0.0001	-	0.01
B - P_6 — find host	uniform	0.01	-	0.1
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
C - P_2 — not detected, packing	uniform	0.01	-	0.1
C - P_3 — survive post harvest	uniform	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.1	-	0.5
C - P_5 — find host	uniform	0.00001	-	0.0001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
D - P_2 — not detected, packing	uniform	0.01	-	0.1
D - P_3 — survive post harvest	uniform	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.1	-	0.5
D - P_5 — find host	uniform	0.01	-	0.1

Table 9. Summary data for scenario analysis / quantitative risk assessment.

Toxoptera citricida - Brown citrus aphid				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
A - P_2 — not detected, packing	uniform	0.01	-	0.03
A - P_3 — survive post harvest	uniform	0.01	-	0.2
A - P_4 — survive shipment	uniform	0.001	-	0.01
A - P_5 — not detected at POE	triangular	0.01	0.02	0.03
A - P_6 — find host	uniform	0.00001	-	0.0001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
B - P_2 — not detected, packing	uniform	0.01	-	0.03
B - P_3 — survive post harvest	uniform	0.01	-	0.2
B - P_4 — survive shipment	uniform	0.001	-	0.01
B - P_5 — not detected at POE	triangular	0.01	0.02	0.03
B - P_6 — find host	triangular	0.1	0.3	0.5
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
C - P_2 — not detected, packing	uniform	0.01	-	0.03
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.0005	-	0.001
C - P_5 — find host	uniform	0.00001	-	0.0001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.0001	-	0.001
D - P_2 — not detected, packing	uniform	0.01	-	0.03
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.0005	-	0.001
D - P_5 — find host	triangular	0.1	0.3	0.5

Table 10. Summary data for scenario analysis / quantitative risk assessment.

Bactrocera tsuneonis - Citrus fruit fly — FLY FREE AREA				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
A - P_2 — not detected, packing	uniform	0.5	-	0.9
A - P_3 — survive post harvest	uniform	0.01	-	0.1
A - P_4 — survive shipment	uniform	0.2	-	0.8
A - P_5 — not detected at POE	uniform	0.5	-	0.9
A - P_6 — find host	uniform	0.00001	-	0.0001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
B - P_2 — not detected,packing	uniform	0.5	-	0.9
B - P_3 — survive post harvest	uniform	0.01	-	0.1
B - P_4 — survive shipment	uniform	0.2	-	0.8
B - P_5 — not detected at POE	uniform	0.5	-	0.9
B - P_6 — find host	normal	-	0.5	(0.1)
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
C - P_2 — not detected, packing	uniform	0.5	-	0.9
C — P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.1	-	0.5
C - P_5 — find host	uniform	0.00001	-	0.0001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,00
D - P_1 — pest present (spatial/temporal)	triangular	0.00001	0.00003	0.0001
D - P_2 — not detected, packing	uniform	0.5	-	0.9
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.1	-	0.5
D - P_5 — find host	normal	-	0.5	(0.1)

Table 11. Summary data for scenario analysis / quantitative risk assessment.

Bactrocera tsuneonis - Citrus fruit fly — FLY INFESTED AREA				
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Most Likely	Maximum *or* (s.d.)
Program Alternative: — A — No Official Preclearance, Fruit to Current States Only				
A - F_1 — cartons imported per year	uniform	40,000	-	200,000
A - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.05
A - P_2 — not detected, packing	uniform	0.5	-	0.9
A - P_3 — survive post harvest	uniform	0.01	-	0.1
A - P_4 — survive shipment	uniform	0.2	-	0.8
A - P_5 — not detected at POE	uniform	0.5	-	0.9
A - P_6 — find host	uniform	0.00001	-	0.0001
Program Alternative: — B — No Official Preclearance, Fruit to All States				
B - F_1 — cartons imported per year	uniform	80,000	-	400,000
B - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.05
B - P_2 — not detected,packing	uniform	0.5	-	0.9
B - P_3 — survive post harvest	uniform	0.01	-	0.1
B - P_4 — survive shipment	uniform	0.2	-	0.8
B - P_5 — not detected at POE	uniform	0.5	-	0.9
B - P_6 — find host	normal	-	0.5	(0.1)
Program Alternative: — C — Official Preclearance, Fruit to Current States Only				
C - F_1 — cartons imported per year	uniform	60,000	-	300,000
C - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.05
C - P_2 — not detected, packing	uniform	0.5	-	0.9
C - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
C - P_4 — survive shipment	uniform	0.1	-	0.5
C - P_5 — find host	uniform	0.00001	-	0.0001
Program Alternative: — D — Official Preclearance, Fruit to All States				
D - F_1 — cartons imported per year	uniform	80,000	-	400,000
D - P_1 — pest present (spatial/temporal)	uniform	0.001	-	0.05
D - P_2 — not detected, packing	uniform	0.5	-	0.9
D - P_3 — survive post harvest	triangular	0.00001	0.00003	0.0001
D - P_4 — survive shipment	uniform	0.1	-	0.5
D - P_5 — find host	normal	-	0.5	(0.1)

Following is a brief discussion of factors that were considered during estimation of probabilities and our rationale for choosing certain input values:

Pest Present (spatial/temporal)

Based on the success of efforts to eliminate citrus canker disease from exporting areas (Kuhara, 1978) and the safeguards of the Unshu orange workplan, we estimated that the probabilities of *X. campestris* pv. *citri* being present in approved groves and escaping detection during pre- and postharvest inspections was exceedingly small. The adoption of an official preclearance program would likely have little effect on those probabilities except that they might decrease slightly as inspections could conceivably be more stringent under a preclearance program.

The probability that a pest would be present in a particular habitat was based primarily on field experience with various insects, literature review, known life cycle of the pest, timing of harvest, and stage of fruit susceptible to attack. Mealybugs were considered to be the most likely arthropod pests present in a production area with the probabilities for the other arthropod pests lower, in the following decreasing order:

- Mealybugs - present throughout the season, often numerous, often found on fruit
- scale insects and mites - present throughout the season, often numerous, found less often on fruit
- *B. tsuneonis* (infested area) - typically with fruit, but highly seasonal and not as abundant
- *D. citri*, *T. citricida* - not often associated with fruit
- *B. tsuneonis* (fly-free area) - probability very low in fly-free area

Estimated probabilities of whether a pest would be present in a growing area was assumed to not vary among program alternatives.

Pest not detected during packing

It was clear that the arthropod pest most difficult to detect would be *B. tsuneonis* because it is an internal feeder. Probabilities of pests escaping detection decreased in the following order:

- *B. tsuneonis* - it would be very difficult to detect this pest on the inside of fruit
- Mites and Mealybugs - outside of fruit but tiny (most intercepted mealybugs are immature and even smaller than the adults and may hide on the fruit)
- Armored scale insects - outside of fruit, larger and easier to see
- *D. citri* and *T. citricida* - it is unlikely that these pests would escape detection, they are relatively large, found on the outside of the fruit, and they move around

The probability that a pest would not be detected during packing did not vary among program alternatives except for *T. citricida*. We assumed that with preclearance, the probability would decrease.

Pest survives post-harvest treatment

Based on efficacy studies (Obata, *et. al.*, 1969; Brown & Schubert, 1987), we considered it highly improbable that *X. campestris* pv. *citri* would survive the postharvest bactericidal fruit dip.

Under the current import program, the only post harvest treatment for arthropods is voluntary fumigation of fruit with methyl bromide. We estimated that these treatments would provide less than probit 9 security (probit 9 = 99.997% mortality). The probability of survival was considered highest for *B. tsuneonis* and decreased as follows:

- *B. tsuneonis*, *T. citricida* - we assumed that *B. tsuneonis* would be relatively immune due to its position inside the fruit and that *T. citricida* could survive due to its high motility
- Mealybugs, Armored scale insects - exterior of fruit but relatively resistant
- Mites, *D. citri* - exterior of fruit

Probabilities for all pests of surviving post-harvest treatments was reduced to probit 9 security with official preclearance programs.

Pest survives shipment

X. campestris pv. *citri* is considered to be a relatively labile bacterium (E.L. Civerolo, personal communication) and it is generally held that populations of *X. campestris* pv. *citri* decline rapidly even within the lesions of infected fruit after harvest (Civerolo, 1981). Even so, in an effort to err on the side of conservatism we estimated that the probability that bacteria, if present, would survive shipment to the United States was relatively high.

There are multiple interception records of mealybugs on shipments of Japanese Unshu orange fruits. This probability was considered to be highest for mealybugs and decreased as follows:

- Mealybugs - multiple interception records
- *B. tsuneonis* - protected within the fruit
- Armored scale insects, *D. citri* - armored scale insects have been intercepted on shipments of Japanese Unshu orange fruits, both are relatively exposed but hardy
- Mites (three species) - exposed but hardy
- *T. citricida* - exposed and fragile

We assumed this probability would be lower for certain pests under programs with official preclearance due to sublethal effects of post-harvest treatments.

Pest escapes port of entry inspection

Only *X. campestris* pv. *citri* occurring within lesions would survive to the port of entry (E.L. Civerolo, personal communication), consequently, for Program Alternatives A and B we estimated that the probability of canker-infected fruit escaping detection at the port of entry to be low.

- *B. tsuneonis* - it would be very difficult to detect this pest on the inside of fruit
- Mites - tiny
- Mealybugs, *T. citricida* - tiny, but more obvious
- Armored scale insects - larger, easier to see and relatively obvious on the outside of fruit
- *D. citri* - it is unlikely that these pests would escape detection, found on the outside of the fruit, and they move around

This probability was not used in scenarios for programs with official preclearance because although all shipments would be subject to inspection, shipments would not necessarily be inspected.

Pest finds suitable host material

We estimated that the probability of *X. campestris* pv. *citri* from imported Unshu orange fruits coming in contact with and infecting suitable host material and becoming established was near zero. We arrived at this estimate by considering the population dynamics of *X. campestris* pv. *citri* on harvested fruit (Civerolo, 1981), the existence of a threshold value for the number of bacteria required to incite an infection even under optimal conditions for disease progression (Goto, *et al.*, 1978), the requirement for host tissue to be in a susceptible stage of development (Anonymous, 1992; Civerolo, 1981; Podleckis, 1995b) and that no authenticated outbreak of citrus canker anywhere in the world has ever been traced to the importation of infected fruit (Anonymous, 1992; Podleckis, 1995b). Importation of Unshu orange fruits into citrus-producing states increases the probability of canker infecting suitable host material but the estimated risk is still nearly zero.

For programs including only non-citrus producing States, this probability was assumed to largely be a function of host specificity for arthropods with the most citrus-specific species having the lowest probability. The probability of finding suitable host material in non-citrus producing States was estimated to be highest for mealybugs and decreased as follows:

- Mealybugs
- Mites
- Armored scale insects, *D. citri*, *T. citricida*, *B. tsuneonis*

For programs including shipment of fruit to citrus producing States, this probability was assumed to be proportional to the motility of the pest. The most motile pest, *B. tsuneonis* was considered to have the highest probability of finding suitable host material in a citrus-producing State. The probabilities for other pests decreased as follows:

- *B. tsuneonis*
- *T. citricida*
- *D. citri*
- Mealybugs
- Mites, Armored scale insects

3. Results: Quantitative Estimates of Establishment Probabilities

Results of the Monte Carlo simulations (*i.e.*, distributions of expected probabilities of establishment of pests) are shown in Tables 12 and 13. Both tables present the same results but Table 12 is organized by pest so that program alternatives can be compared for given pests, and Table 13 is organized by program alternative so that the program alternatives can be compared more easily. Two types of probabilities are given. Details of the probability distributions (*i.e.*, the mode and mean of the probability distribution, and the minimum and maximum values) are given in terms of establishment frequency. The establishment frequency provides our estimate for the probability in any given year that the pest could become established in the U.S. as a result of Japanese Unshu orange fruit importations. When the establishment frequency is greater than one (*e.g.*, *B. tsuneonis* from a fly-infested area under program alternative B) it is estimated that multiple establishments will occur each year. Estimates are also provided in terms of the number of years between establishment events (last column in Tables 12 and 13). For all but one case (*i.e.*, *B. tsuneonis* from a fly-infested area under program alternative B) the interval between establishment events is greater than one year.

Table 12. Likelihood of Establishment, Japanese Citrus Pests: Organized By Pest

Pest	Program	Establishment Frequency (establishment events per year)				Number of years between establishment events [2]
		Mode[1]	Mean[1]	Minimum[1]	Maximum [1]	
Xanthomonas campestris pv. *citri*	A	7.52×10^{-22}	2.17×10^{-21}	1.14×10^{-24}	3.01×10^{-20}	> million
	B	1.51×10^{-21}	4.34×10^{-21}	2.27×10^{-24}	6.01×10^{-20}	> million
	C	1.78×10^{-18}	6.45×10^{-18}	1.01×10^{-20}	7.07×10^{-17}	> million
	D	2.37×10^{-16}	8.61×10^{-16}	1.35×10^{-18}	9.42×10^{-15}	> million
Mites	A	0.00128	0.00172	0.00000118	0.051	781
	B	0.00219	0.00326	0.00000292	0.0873	11
	C	0.0000116	0.0000279	0.000000239	0.000455	86,207
	D	0.0000155	0.0000372	0.000000319	0.000607	64,516
Mealybugs	A	0.0985	0.328	0.00289	3.827	10
	B	0.197	0.656	0.00577	7.655	5
	C	0.00279	0.0142	0.000463	0.0937	358
	D	0.00373	0.0189	0.000618	0.125	268
Armored scale insects	A	0.00000954	0.0000257	5.29×10^{-8}	0.000380	104,822
	B	0.00188	0.00469	0.00000626	0.0750	532
	C	2.32×10^{-8}	6.44×10^{-8}	4.79×10^{-10}	9.10×10^{-7}	> million
	D	0.00000281	0.00000713	1.04×10^{-8}	0.000112	355,872
Diaphorina citri	A	5.20×10^{-11}	1.50×10^{-10}	1.52×10^{-13}	2.08×10^{-9}	> million
	B	0.000000104	0.000000299	3.04×10^{-10}	0.00000415	> million
	C	1.30×10^{-9}	3.88×10^{-9}	4.04×10^{-11}	5.05×10^{-8}	> million
	D	0.00000174	0.00000518	5.39×10^{-8}	0.0000674	574,712
Toxoptera citricida	A	2.42×10^{-10}	7.65×10^{-10}	3.58×10^{-12}	9.52×10^{-9}	> million
	B	0.00000244	0.00000839	6.00×10^{-8}	0.0000954	409,836
	C	8.48×10^{-13}	3.63×10^{-12}	7.57×10^{-14}	3.10×10^{-11}	> million
	D	6.20×10^{-9}	2.65×10^{-8}	7.91×10^{-10}	2.17×10^{-7}	> million

[1] - See text for description of these terms.
[2] - Calculated as inverse of mode.

Table 12 (cont). Likelihood of Establishment, Japanese Citrus Pests: Organized By Pest

Pest	Program	Establishment Frequency (establishment events per year)				Number of years between establishment events [2]
		Mode[1]	Mean[1]	Minimum[1]	Maximum[1]	
Bactrocera tsuneonis Fruits from fly-free area	A	9.34×10^{-7}	0.00000382	7.20×10^{-8}	0.0000346	> million
	B	0.0164	0.0700	0.00195	0.579	61
	C	1.06×10^{-9}	4.30×10^{-9}	6.76×10^{-11}	4.00×10^{-8}	> million
	D	0.0000133	0.0000524	0.00000172	0.000463	75,188
Bactrocera tsuneonis Fruits from fly infested area	A	0.000511	0.00207	0.0000100	0.0200	1,957
	B	8.643	37.884	0.259	335.627	0.116
	C	0.000000602	0.00000236	1.34×10^{-8}	0.0000236	> million
	D	0.00701	0.0288	0.000187	0.273	143

[1] - See text for description of these terms.
[2] - Calculated as inverse of mode.

Table 13. Likelihood of Establishment, Japanese Citrus Pests: Organized By Program

Program Alternative	Pest	Establishment Frequency (establishment events per year)				Number of years between establishment events [2]
		Mode[1]	Mean[1]	Minimum[1]	Maximum[1]	
A No Official Preclearance Orange Fruits to Current States only	*Xanthomonas campestris* pv. *citri*	7.52 X 10^{-22}	2.17 X 10^{-21}	1.14 X 10^{-24}	3.01 X 10^{-20}	> million
	Mites	0.00128	0.00172	0.00000118	0.051	781
	Mealybugs	0.0985	0.328	0.00289	3.827	10
	Armored scale insects	0.00000954	0.0000257	5.29 X 10^{-8}	0.000380	104,822
	Diaphorina citri	5.20 X 10^{-11}	1.50 X 10^{-10}	1.52 X 10^{-13}	2.08 X 10^{-9}	> million
	Toxoptera citricida	2.42 X 10^{-10}	7.65 X 10^{-10}	3.58 X 10^{-12}	9.52 X 10^{-9}	> million
	Bactrocera tsuneonis fly free area	9.34 X 10^{-7}	0.00000382	7.20 X 10^{-8}	0.0000346	> million
	Bactrocera tsuneonis infested area	0.000511	0.00207	0.0000100	0.0200	1,957
B No Official Preclearance Orange Fruits to All States	*Xanthomonas campestris* pv. *citri*	1.51 X 10^{-21}	4.34 X 10^{-21}	2.27 X 10^{-24}	6.01 X 10^{-20}	> million
	Mites	0.00219	0.00326	0.00000292	0.0873	11
	Mealybugs	0.197	0.656	0.00577	7.655	5
	Armored scale insects	0.00188	0.00469	0.00000626	0.0750	532
	Diaphorina citri	0.000000104	0.000000299	3.04 X 10^{-10}	0.00000415	> million
	Toxoptera citricida	0.00000244	0.00000839	6.00 X 10^{-8}	0.0000954	409,836
	Bactrocera tsuneonis fly free area	0.0164	0.0700	0.00195	0.579	61
	Bactrocera tsuneonis infested area	8.643	37.884	0.259	335.627	0.116

[1] - See text for description of these terms.
[2] - Calculated as inverse of mode.

Table 13 (cont). Likelihood of Establishment, Japanese Citrus Pests: Organized By Program

Program Alternative	Pest	Establishment Frequency (establishment events per year)				Number of years between establishment events [2]
		Mode[1]	Mean[1]	Minimum[1]	Maximum[1]	
C Official Preclearance Orange Fruits to Current States only	*Xanthomonas campestris* pv. *citri*	1.78×10^{-18}	6.45×10^{-18}	1.01×10^{-20}	7.07×10^{-17}	> million
	Mites	0.0000116	0.0000279	0.000000239	0.000455	86,207
	Mealybugs	0.00279	0.0142	0.000463	0.0937	358
	Armored scale insects	2.32×10^{-8}	6.44×10^{-8}	4.79×10^{-10}	9.10×10^{-7}	> million
	Diaphorina citri	1.30×10^{-9}	3.88×10^{-9}	4.04×10^{-11}	5.05×10^{-8}	> million
	Toxoptera citricida	8.48×10^{-13}	3.63×10^{-12}	7.57×10^{-14}	3.10×10^{-11}	> million
	Bactrocera tsuneonis fly-free area	1.06×10^{-9}	4.30×10^{-9}	6.76×10^{-11}	4.00×10^{-8}	> million
	Bactrocera tsuneonis infested area	0.000000602	0.00000236	1.34×10^{-8}	0.0000236	> million
D Official Preclearance Orange Fruits to All States	*Xanthomonas campestris* pv. *citri*	2.37×10^{-16}	8.61×10^{-16}	1.35×10^{-18}	9.42×10^{-15}	> million
	Mites	0.0000155	0.0000372	0.000000319	0.000607	64,516
	Mealybugs	0.00373	0.0189	0.000618	0.125	268
	Armored scale insects	0.00000281	0.00000713	1.04×10^{-8}	0.000112	355,872
	Diaphorina citri	0.00000174	0.00000518	5.39×10^{-8}	0.0000674	574,712
	Toxoptera citricida	6.20×10^{-9}	2.65×10^{-8}	7.91×10^{-10}	2.17×10^{-7}	> million
	Bactrocera tsuneonis fly free area	0.0000133	0.0000524	0.00000172	0.000463	75,188
	Bactrocera tsuneonis infested area	0.00701	0.0288	0.000187	0.273	143

[1] - See text for description of these terms.
[2] - Calculated as inverse of mode.

Table 12 shows clear patterns in risks posed by the various pests. The probability that Citrus Bacterial Canker could become established in the U.S. as a result of importations of Japanese Unshu orange fruit is orders of magnitude lower than any of the arthropod pests, regardless of the program alternative. The two disease vectors have the next lowest estimated probability of establishment, regardless of program alternative. The highest risk pest appears to be mealybugs; this corresponds to the multiple mealybug interceptions in shipments of Japanese Unshu orange fruits (the estimate is partly a consequence of these interceptions). The next highest risk pest group is mites followed by armored scale insects. Although the risk posed by *B. tsuneonis* was highly dependent on the program alternative considered, this pest appears to pose the greatest risk under particular program alternatives.

Certain patterns among program alternatives are shown in Table 13, although the patterns do not necessarily hold for all pests. In general, the lowest probabilities of establishment were estimated for program alternative C (official preclearance with fruits going only to current States). The program alternative presenting the greatest estimated risk of establishment of quarantine pests was alternative B (no official preclearance with fruits going to all States). Although alternative D (official preclearance with fruits going to all States) appears to present a risk slightly greater than alternative C (primarily because citrus hosts would be available), risks posed under alternative D are estimated to be low (with the possible exception of fruit grown in area infested with *B. tsuneonis* and mealybugs.

V. Recommendations

New production areas are Saga, Fukuoka, Kumamoto, Nagasaki prefectures west of the central mountains of Kyushu, where trapping data and fruit cutting evidence suggest that the fruit fly is not likely to occur. The citrus fruit fly, *B. tsueonis*, is known to occur only in prefectures east of the central mountains on Kyushu and on Amami island. Because of the potential pest load involved, particularly citrus canker, and now *B. tsuneonis*, and with a history of interception records of exotic mealybugs and the armored scale, *Unaspis yanonensis*, we believe that the following mitigation options, singly or in combination, should be considered:

<u>Mitigation Options</u>

1. Present work plan - no change.
2. Present work plan with mandatory treatments (methyl bromide) for microarthropods and with following options for *Bactrocera tsueonis*:
   a. Mandatory treatment (methyl bromide)
   b. Fruit fly free zone (by definition 319.56-2(f))
   c. Systems approach similar to Florida Caribbean fruit fly protocol
3. Biometric sampling
4. Full preclearance at origin
5. Optional treatments such as oil/soapy water dips.
6. Port of entry inspections
7. Trial period: Kyushu fruit fly protocol to non citrus production states
8. Other options

These and other options will be considered and rated in a separate risk management process.

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Carl Childers, University of Florida Citrus Research Center prepared the original draft of the arthropod pest list. His efforts are greatly appreciated and the value of his work cannot be overestimated. APHIS takes full responsibility for any errors in the final version of the pest list.

A draft of the pest list was reviewed by officials (State and Federal) in all five citrus-producing States:

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VIII. Appendices

Appendix 1:	Letter regarding Black Spot
Appendix 2:	Pest Data Sheet: Citrus Greening
Appendix 3:	Pest Data Sheet: Citrus Bacterial Canker
Appendix 4:	Pest Data Sheet: *Eotetranychus kankitus* Ehara
Appendix 5:	Pest Data Sheet: *Eotetranychus asiaticus* Ehara
Appendix 6:	Pest Data Sheet: *Tetranychus kanzawai* Kishida
Appendix 7:	Pest Data Sheet: *Parlatoria cinerea* Hadden
Appendix 8:	Pest Data Sheet: *Planococcus lilacinus* (Cockerell)
Appendix 9:	Pest Data Sheet: *Planococcus kraunhiae* Kuwana
Appendix 10:	Pest Data Sheet: *Pseudococcus cryptus* Hempl
Appendix 11:	Pest Data Sheet: *Unaspis yanonensis* Kuwana
Appendix 12:	Pest Data Sheet: *Toxoptera citricida* Kirkaldy
Appendix 13:	Pest Data Sheet: *Diaphorina citri* Kuway
Appendix 14:	Pest Data Sheet: *Bactrocera tsuneonis* Miyake
Appendix 15:	Pest Risk Assessment of Armored Scales on Certain Fruit

(3)

April 10, 1967

Dr. E. C. Calavan
Dept. of Plant Pathology
University of California
Riverside, California

Dear Dr. Calavan:

Geographic Distribution of *Guignardia citricarpa* in Japan.

At one time it was believed that small irregular markings on citrus fruits in Japan were caused by *Guignardia citricarpa*. Japanese workers now believe, and I fully agree with them, that these markings are due to mechanical or insect injury. The culturing of the latent, non-pathogenic type of *G. citricarpa* from the markings was responsible for the confusion.

During my visit to Japan I was able to find the non-pathogenic *G. citricarpa* without difficulty on dead leaves of Unshu at Matsuyama and south of Tokyo. So the non-pathogenic strain is probably present in most citrus orchards in Japan.

A very low percentage of stored Unshu fruit develop a decay caused by a fungus which a Japanese worker named *G. citricarpa* var. *Mikan*. The varietal status was based on size of pycnidiospores and rotting of Unshu. But I have found that the non-pathogenic *G. citricarpa* from hosts other than citrus will cause a similar decay of Unshu after inoculation of mature fruit. (Navels, other mandarins, lemons, valencias and grapefruit do not respond similarly.) Because of this and because Lee (China) found that spores of isolates from decayed fruit varied in size I believe that the var. *Mikan* is really the common "non-pathogenic" *G. citricarpa*.

As far as I can determine there is no evidence that the black spot pathogen occurs in Japan.

I hope this letter reaches you on time and that your questions have been answered satisfactorily.

Yours sincerely,

K. C. McOnie
Associate Plant Pathologist

KCM:cb

APPENDIX 1

PEST DATA SHEET

CITRUS GREENING BACTERIUM

IDENTITY

Name: Citrus greening bacterium (no scientific name)

Synonym: None

Taxonomic position: A fastidious, phloem limited, Gram-negative bacterium that is not yet otherwise classified. Occurs in a heat sensitive (African) form and a heat tolerant (Asian) form.

Common names: Citrus greening, decline, huang long bin, likubin, leaf mottling, vein phloem degeneration, yellow shoot

MAIN DISEASE

Citrus greening severely affects the phloem tissue of citrus trees concomitantly causing a general decline of affected trees which fail to reach production or, if infected as mature trees, become unproductive (Whiteside, *et. al.*, 1988).

HOST RANGE

The bacterium may persist and multiply in trees of most *Citrus* spp., but the most severe symptoms are seen in oranges (*C. sinensis*), mandarins (*C. reticulata*) and tangelos (*C. reticulata* X *C. paradisi*). Symptoms are somewhat less severe in lemons (*C. limon*), grapefruits (*C. paradisi*), Rangpur lime (*C. limonia),* sweet lime (*C. limettioides*), rough lemon (*C. jambhiri*), kumquat (*Fortunella* spp.) and citrons (*C. medica*). Limes (*C. latifolia*) and pummelos (*C. grandis*) are even less severely affected. The citrus greening bacterium has been experimentally transmitted to periwinkle (*Catharanthus roseus*) using dodder. The arthropod vectors of citrus greening, the psyllids *Diaphorina citri* and *Trioza erytreae* (Homoptera: Psyllidae) are confined to hosts in the Rutaceae including *Citrus* spp., wild hosts (*Clausena anisata, Vespris undulata*) and the ornamental *Murraya paniculata.*

GEOGRAPHIC DISTRIBUTION

<u>Heat sensitive form</u>: Asia (Saudi Arabia, Yemen), Africa (Comoros, Ethiopia, Kenya, Madagascar, Mauritius, Réunion, South Africa, Swaziland, Zimbabwe)(Anonymous, 1992).

Heat tolerant form: Asia (Peoples Republic of China, India, Indonesia, Japan, Malaysia, Nepal, Pakistan, Philippines, Saudi Arabia, Taiwan, Thailand), Africa (Mauritius, Réunion)(Anonymous, 1992; Miyakawa and Tsuno, 1989).

BIOLOGY

The citrus greening bacterium exists in two forms (Bové, 1974). The heat sensitive form occurs in southern Africa and does not produce symptoms when temperatures exceed 30°C for more than a few hours daily. The heat tolerant form can withstand these high temperatures and is primarily Asian in distribution. Monoclonal antibodies produced against an isolate of the heat tolerant form reacted with isolates of the heat sensitive form suggesting that the two forms are serologically related (Garnier, *et al.*, 1991). In nature, the citrus greening bacterium is transmitted by *T. erytreae* in Africa and *D. citri* in Asia. Population fluctuations of the vectors are correlated with the flushing rhythm of *Citrus* spp. since eggs are laid on young flush points. Experimental transmission studies have demonstrated that both vectors can transmit either form of citrus greening (Massonie, *et al.,* 1976; Lallemand, *et al.*, 1986).

DETECTION AND IDENTIFICATION

Symptoms

Trees initially show leaf mottling and chlorosis symptoms followed by twig dieback and a general decline of the tree. Fruit are reduced in number and size. Seed are frequently aborted in affected fruit. Some fruit are under- developed, lopsided and poorly colored. The greening symptom seen in Africa, develops when fruit mature only on the side exposed to the sun while the unexposed side remains green. Feeding and oviposition by the vector, *D. citri*, causes stunting and twisting of young shoots, severe leaf curl and premature leaf abscission. Honeydew and sooty mold may also be present. *T. erytreae* distorts leaves which are stunted and galled, and may appear to be dusted with fecal matter (Anonymous, 1992).

Morphology

Two forms of the organism have been described: elongated, rod-like structures 0.15-0.25 μm in diameter and 1.0-4.0 μm long, and round forms ranging from 0.3-1.0 μm in diameter. Both forms have been visualized, by electron microscopy, in sieve elements of infected citrus trees and periwinkle (Garnier, *et al.*, 1991).

Detection and inspection methods

The preferred detection methods for citrus greening are electron microscopy or graft indexing of suspect material onto seedlings of sweet orange or Orlando tangelo. Mandarin or grapefruit may also be used as indicator hosts. The preferred inoculum is leaves expressing mottling symptoms and at least ten indicator trees per test should be inoculated. After inoculation, the indicators should be maintained at 24°C for heat sensitive forms or 32°C for the heat tolerant form. Symptoms usually appear within 4-5 months, but may require as long as 6-12 months (Anonymous, 1992; Frison and Taher, 1991). Monoclonal antibodies prepared against Indian and Chinese isolates have been successfully used to detect the bacterium by immunofluorescence and ELISA (Garnier, *et al.*, 1991).

MEANS OF MOVEMENT AND DISPERSAL

Citrus greening is transmitted by grafting and vectored by two species of citrus psyllid, *D. citri* and *T. erytreae*. It has been transmitted experimentally by dodder and is not seed transmitted. The citrus greening bacterium can be moved by its vectors or in citrus plants. The two vectors of greening bacterium are not present in the U.S. so the introduction of infected plant material may not result in the spread of the disease other than by propagation of infected plant material. Because the vectors preferentially attack young vegetative growth and the pathogen is phloem restricted, fruit is unlikely to provide a pathway for the introduction of the citrus greening bacterium. The pathogen is propagative in the vector and there is a 1-3 week incubation period between acquisition and the time insects become infective. Neither psyllid is regarded as an efficient vector and rapid natural spread occurs only when there are high concentrations of inoculum and high populations of the vectors.

PEST SIGNIFICANCE

Economic impact

Citrus greening is an extremely severe disease. Greening has virtually destroyed flourishing citrus industries in the Philippines, Taiwan, Indonesia and portions of India and China. In the Philippines, mandarin production fell from 11,887 metric tons in 1960 to 102 metric tons in 1968. In South Africa, in 1965, fruit losses from the disease were 30-100% in individual orchards.

Control

Greening affected trees respond to antibiotic treatment, but these are not curative and are of questionable economic value. Good sources of host tolerance or resistance are limited. In areas where greening has become established, it has been controlled either through biological control of the vector or a combination of removal of infected trees, vector control, disease-free nursery stock and rouging of recently infected plants.

Phytosanitary risk

Citrus greening bacterium is listed as a quarantine pest by EPPO and is also of quarantine significance to COSAVE, CPPC and IASPC. Chances of the introduction of both the pathogen and its vector and establishment of a biologically significant reservoir of inoculum are not high given current certification and regulatory programs. However, if entry does occur, the potential for economic damage is great. Consequently, it is essential to exclude the pathogen and its vector from the U.S.

PHYTOSANITARY MEASURES

Importation of plant parts, except fruit and seeds, of *Citrus* spp. and related hosts of the citrus greening bacterium or its vectors, should be prohibited from countries where citrus greening or its vectors occur. Healthy budwood can be obtained by shoot tip grafting and heat treatment of budwood in a tetracycline solution or both. Pathogen-free material should be maintained and propagated under insect-proof conditions and indexed periodically. It is possible to fumigate citrus budwood to eliminate either vector species (FAO, 1983).

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APPENDIX 2

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March, 1995

APPENDIX 2

PEST DATA SHEET

XANTHOMONAS CAMPESTRIS PV. *CITRI*
CITRUS CANKER

IDENTITY

Name: *Xanthomonas campestris* (Pammel) Dowson pv. *citri* (Hasse)

Synonyms: *Pseudomonas citri* Hasse
Xanthomonas citri (Hasse) Dowson
Xanthomonas citri (Hasse) Dowson f.sp. *aurantifolia* Namekata & Oliveira
Xanthomonas campestris (Pammel) Dowson pv. *aurantifolii* Gabriel, *et al.*

Taxonomic position: Bacteria: Gracilicutes

Common names: Citrus canker, bacterial canker of citrus, citrus bacterial canker, Asiatic canker, canker A, cancrosis A, canker B, cancrosis B, canker C, Mexican lime cancrosis, canker D, citrus bacteriosis

Notes on taxonomy: Several changes in the taxonomic status of *X. campestris* pv. *citri* have been proposed (Gabriel, *et al.*, 1989). These include the reinstatement of some strains of pv. *citri* to species level as *X. citri* and the assignment of others to *X. campestris* pv. *aurantifolii*. To date, these revisions have not been universally adopted and the A, B, C and D strains have remained classified as *X. campestris* pv. *citri*. The name *X. campestris* pv. *citrumelo* has been proposed (Gabriel, *et al.*, 1989), though not officially adopted, for the E strain identified in 1984 in Florida citrus nurseries as the cause of citrus bacterial spot disease. In 1990, all regulations of the citrus bacterial spot or E strain of *X. campestris* pv. *citri* (*X. campestris* pv. *citrumelo*) were removed based on scientific evidence and experience in Florida that indicated that none of the E strain forms causes a disease dangerous to citrus or other plants or fruit (Graham & Gottwald, 1991). This rule change effectively removes the citrus bacterial spot or E strain from consideration as a quarantine pest. This data sheet, therefore, will not address the citrus bacterial spot or E strain.

MAIN DISEASE

X. campestris pv. *citri*, the causal agent of citrus canker disease, can attack twigs, leaves and fruit of most commercial citrus tree cultivars, as well as other members of the Rutaceae. Citrus canker is primarily a leaf-spotting and rind- blemishing disease, but under favorable conditions fruit drop, defoliation and general decline of nursery stock and producing trees can also occur (Whiteside, *et al.*, 1988).

HOST RANGE

Known hosts are in the family Rutaceae. Citrus is the main host of economic importance. The majority of commercially important *Citrus* spp. and their hybrids are susceptible. In general, grapefruit (*C. paradisi*) is extremely susceptible. Trifoliate orange (*Poncirus trifoliata*), lime (*C. aurantifolia*), sweet orange (*C. sinensis*), sour orange (*C. aurantium*) and lemon (*C. limon*) are all considered susceptible while pummelo (*C. grandis*) and mandarin (*C. reticulata*) are considered moderately resistant. Calmondin orange (*C. mitis*), citron (*C. medica*) and kumquat (*Fortunella margarita*) are highly resistant (Fawcett, 1936). Other rutaceous hosts include *Aegle marmelos, Atalantia* spp., *Balsamocitrus paniculata, Casimiroa edulis, Chaetospermium glutinosa, Citropsis schweinfurthii, Clausena lansium, Eremocitrus glauca, Evodia* spp., *Feronia* spp., *Feroniella* spp., *Hesperethusa crenulata, Limonia* spp., *Melicope triphylla, Microcitrus* spp., *Murraya exotica, Paramigyna longipedunculata, Severina buxifolia, Toddalia asiatica* and *Zanthoxylum* spp. (Swings and Civerolo, 1993). One non-rutaceous host, *Lansium domestica* (Meliaceae), has been reported (Anonymous, 1992). Canker A and B strains have similar host ranges while the C and D strains affect only limes (*C. aurantiifolia*).

GEOGRAPHIC DISTRIBUTION

Citrus canker disease probably originated in Southeast Asia and was subsequently spread throughout Asia then to Africa, Oceania and the Americas. The disease has been reported on islands in the Indian Ocean and in the Middle East. Mild strains with a narrower host range than the Asiatic or A strain were reported in South America (cancrosis B, canker C and D). These have not been isolated from naturally-infected trees since the mid-1980's (Anonymous, 1992). **Asia** (Afghanistan, Andaman Islands, Bangladesh, Cambodia, People's Republic of China, Hong Kong, India, Indonesia, Iran, Japan (including Okinawa), Kampuchea, Korea Democratic People's Republic, Republic of Korea, Laos, Malaysia, Maldives, Myanmar, Nepal, Oman, Pakistan, Philippines, Ryuku Islands, Saudi Arabia, Singapore, Sri Lanka, Taiwan, Thailand, United Arab Emirates, Vietnam, Yemen); **Africa** (Comoro Islands, Peoples Republic of Congo, Côte d'Ivoire, Gabon, Madagascar, Mauritius, Morocco, Mozambique (reportedly eradicated), Réunion Island, Rodrigues Islands, Seychelles Islands, South Africa (eradicated), Zaire); **North America** (Mexico-D strain only (reportedly eradicated), U.S. (Asiatic or A strain introduced into FL in 1912, spread to AL, GA, LA, SC, TX; eradicated from FL by 1933, from U.S. by 1947; reappeared in FL in 1986 and was declared eradicated in 1994); **Central America and Caribbean** (Unconfirmed reports from Belize, Dominica, Guadeloupe, Haiti, Martinique, St. Lucia, Trinidad and Tobago); **South America** (Argentina- A&B strains, Brazil- A&C strains, Paraguay- A,B&C strains, Uruguay- A strain, B strain eradicated); **Oceania** (Caroline Islands, Christmas Island, Cocos Islands, Fiji, Guam, Mariana Islands, Micronesia, Papua New Guinea, Thursday Island(eradicated, 1991); reportedly eradicated from commercial citrus producing areas of Australia and New Zealand; reappeared in Australia in 1990.) (Anonymous, 1992; Anonymous, 1982).

BIOLOGY

Several strains of *X. campestris* pv. *citri* are known(see Taxonomy notes above): the A or Asiatic strain causes typical citrus canker disease; the B or cancrosis B strain from South America has a host range similar to the A strain but produces milder symptoms; the C strain affecting Key lime (*C. aurantifolia*) in Brazil; the D strain which has been reported from Mexico infecting twigs and leaves, but not fruit, of grapefruit (*C. paradisi*) and Key lime; and the E strain causing citrus bacterial spot in Florida. *X. campestris* pv. *citri* overwinters in lesions formed on leaves and twigs the previous growing season. Bacteria from these overwintering lesions are the primary inoculum during the spring. During warm (20 - 30°C), wet weather of spring and early summer, the bacteria ooze out of the overwintering lesions and are splashed or wind blown to young, actively growing leaves, shoots and fruits. Infection occurs through natural openings (*eg.*, stomata) or wounds. A film of moisture is necessary for infection to occur. Leaf infection can occur within 14 - 21 days after shoots begin to develop. Infection rarely occurs until leaves are about 85 % expanded (Ferguson, *et al.*, 1985). Fruit are generally susceptible to infection during expansion when they are 3-6 cm in diameter and may remain susceptible for 60 - 90 days after petal fall. Resistance of leaves, stems and fruit increases with tissue maturation (Civerolo, 1981). Multiplication occurs in the host tissues a7 14 - 36°C with the optimum temperature being 25 - 30°C. Generally, *X. campestris* pv. *citri* populations decline very rapidly in soil, in lesions on defoliated leaves and dropped fruit and in infested host and nonhost tissues (*ie.*, roots) (Civerolo, 1981), but *X. campestris* pv. *citri* can be detected for as long as 120 days in decomposing citrus leaf tissues. Burial of the leaves reduces the survival time to 85 days and irrigation to increase soil moisture and hasten leaf decomposition further reduces survival time to 24 days (Graham, *et al.*, 1987). In the presence of living citrus tissue, *X. campestris* pv. *citri* can survive as long as 10 months (Goto, *et al.*, 1978). Killing of citrus plants with fumigants provides an alternative to removing plants during eradication. If all host tissue is killed, *X. campestris* pv. *citri* would not be expected to survive more than 6 months (Graham, *et al.*, 1987). *X. campestris* pv. *citri* has also been reported to survive on grasses that grow near infected citrus. In Brazil, the bacterium was found on sourgrass (*Trichachne insularis*) (Lima, 1977) and in Japan, *X. campestris* pv. *citri* has been found on two species of *Zoysia* (Goto, *et al.*, 1975, 1978). It is uncertain whether the low populations found in soil, debris and nonhost tissues plays a role as inoculum for susceptible tissues (Serizawa, 1981).

DETECTION AND IDENTIFICATION

Symptoms

X. campestris pv. *citri* infects above ground parts of susceptible hosts including leaves, twigs, stems, trunk, thorns and fruit. Leaf symptoms first appear as small, pinpoint spots that become raised above the leaf surface. The spots initially appear on the lower leaf surface but eventually become visible on the upper surface. Early lesions have a water-soaked, translucent appearance. The leaf epidermis eventually ruptures and the lesions become sunken and crater-like. Lesions may be surrounded by a yellow halo and the central necrotic region becomes surrounded by a water-soaked oily or greasy margin. As lesions age and expand to 9 - 10 mm in diameter, the necrotic centers may drop out producing a shot hole symptom. Lesions on shoots and twigs resemble those on leaves except that they may lack the chlorotic halo and are larger (up to 15 cm). Lesions on fruit may or may not be surrounded by a chlorotic halo and are more sunken than leaf lesions and are larger (3 - 6 cm). The lesions on fruit do not penetrate the rind more than 1 - 3 mm (Anonymous, 1982; Anonymous, 1992).

Morphology

X. campestris pv. *citri* is a short, motile rod-shaped bacterium measuring 0.5 - 0.75 μm wide by 1.5 - 2.0 μm long with a single, polar flagellum. The rods are single or in chains, but are more often paired. Colonies on beef extract agar are round, range from hay yellow to amber in color, are slightly elevated, lustrous with continuous margins and viscid. Characteristic growth of *X. campestris* pv. *citri* colonies on potato produce a yellow, lustrous colony surrounded by a narrow white zone that subsequently disappears leaving the entire potato slice enveloped in a thick yellow slime (Kothekar, 1978).

Detection and inspection methods

Serological tests using polyclonal and monoclonal antibodies, bacteriophage sensitivity assays, plasmid DNA content analysis, genomic DNA fingerprinting, restriction fragment polymorphism analysis, SDS polyacrlamide gel electrophoresis and fatty acid composition analysis have all been successfully employed to detect or identify *X. campestris* pv. *citri*. Despite recent technological advances, conclusive identification of *X. campestris* pv. *citri* is based on pathogenicity tests using inoculation of *Citrus* spp.

MEANS OF MOVEMENT AND DISPERSAL

Short distance dispersal of the pathogen in groves occurs primarily by wind driven rain. Rain and wind in excess of 6 - 8 m/sec cause the water soaking in leaves necessary for infection and cause entrance wounds when shoots are injured by wind whipping. Overhead irrigation may also play a role in short distance spread as may mechanical equipment used in grove maintenance (Ferguson, *et al.*, 1985; Swings & Civerolo, 1993).

Long distance spread of *X. campestris* pv. *citri* has occurred primarily through the movement of infected planting and propagating materials. Long distance spread via animals, birds and insects has been suggested but not confirmed. Seed transmission is not known. Infested personnel, clothing, equipment, tools, field boxes, trucks and other items used in harvest and post harvest could potentially facilitate long distance spread of *X. campestris* pv. *citri*. The pathogen could potentially move long distances on diseased fruit, but there is no authenticated example of a disease outbreak that initiated from diseased fruit. Untreated, infected culled fruit or pulp could also provide a pathway for long distance spread (Anonymous, 1992; Swings & Civerolo, 1993).

PEST SIGNIFICANCE

Economic impact

Citrus canker is a severe disease adversely affecting all of the above ground plant parts of citrus trees. *X. campestris* pv. *citri* causes leaf and twig spotting , rind blemishes and in severe cases, premature fruit drop. In all countries where it is reported, canker is one of the most damaging diseases of citrus, especially where defoliation and fruit drop occur. Internal quality of fruit that matures on the tree is unaffected, but the fresh market value is greatly reduced and the lesions provide entry wounds for secondary fruit rotting organisms (Anonymous, 1992). In the 23 years from 1910 to 1933 when *X. campestris* pv. *citri* was eradicated in Florida, over $6 million was spent on the program and 258,000 grove trees and 3 million nursery trees were destroyed (Ferguson, *et al.*, 1985). In the four years following the outbreak of first citrus bacterial spot and then citrus canker in Florida, over 20 million trees were destroyed at a cost of nearly $94 million (Graham & Gottwald, 1991).

Control

The most effective control of citrus canker disease, where it has become established, is supplementing the use of resistant planting material with preventive cultural practices. In Japan, one of the single most effective control measures is the use of windbreaks (Kuhara, 1978). Removal of overwintering inoculum by pruning infected shoots and defoliation or eradication of infected trees can reduce inoculum for primary and secondary infections. Avoidance of working trees when wet, disinfestation of tools and equipment , protective sprays of copper- containing pesticides during periods when leaves and fruit are susceptible, and control of leaf miners and the wounds they cause, may all serve to reduce the incidence of citrus canker disease (Anonymous, 1992).

Phytosanitary risk

X. campestris pv. *citri* is listed as a quarantine pest by EPPO, IAPSC, JUNAC and NAPPO. *X. campestris* pv. *citri* is listed as a quarantine pest by the United States and fruit, nursery stock and plant parts are regulated (7CFR § 301.75. 1994, 7CFR § 301.83. 1994, 7CFR § 319.19. 1994 & 7CFR § 319.28. 1994) (Anonymous, 1994a, 1994b, 1994c, 1994d).

PHYTOSANITARY MEASURES

All plant parts of rutaceous hosts of *X. campestris* pv. *citri*, except seeds and tissue cultures, should be prohibited from countries where the bacterium occurs.

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APPENDIX 3

PEST DATA SHEET

<u>Eotetranychus</u> <u>kankitus</u> Ehara

TAXONOMY
Name: <u>Eotetranychus</u> <u>kankitus</u> Ehara
Synonymy: None
Classification: Acari:Tetranychidae
Common name: Citrus yellow mite

HOSTS
Reported on *Citrus sp.* in Japan and on citrus, peach, grape, *etc.* in China.

GEOGRAPHIC DISTRIBUTION
Asia: Japan (Shikoku), China

LIFE HISTORY
Biology and injury is similar to *E. sexmaculatus* which is primarily a pest of the leaf. However, in heavy populations, mites may be found on the fruit. In China, there are two population peaks in spring, one in March and April, and the other in June. The population density of the first peak often appears to be the higher, resulting in serious infestation. Serious damage is caused during the warmer, drier weather when the spring flush elongates. In China, the mites oviposit and hatch out at about 5deg C. in winter. Some of the winter eggs will go into diapause. In Japan this mite may overwinter at any stage.

DETECTION AND IDENTIFICATION
On propagation: any life stage.
On non-propagation: Mites in webbing, in calyx or other cavity in fruit.
Morphology: Jeppson, <u>et al</u>, 1975.

MOVEMENT AND DISPERSAL
Natural spread: Wind and rain, animals. Wind will blow mites onto neighboring fields.
Man-assisted spread: Nursery stock, movement of equipment in the field.

PEST SIGNIFICANCE
Economic impact: The mite is a leaf feeder and recorded from a variety of economic crops. Its impact would be similar to the six-spotted spider mite, (*E. sexmaculatus*).

PHYTOSANITARY MEASURES
Treatment: Fumigation.
Other safeguards: Destruction of containers.

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PEST DATA SHEET

Eotetranychus asiaticus Ehara

IDENTITY

Name: *Eotetranychus asiaticus* Ehara
Synonymy: None
Classification: Acari:Tetranychidae
Common names: Braune Citrusblattlaus, Brown Citrus Aphid, Oriental Black Citrus Aphid, Puceron tropical de l'oranger, Pulgon cafe de los citros, Tropical Citrus Aphid.

HOSTS

Reported on *Citrus* sp., *Diospyros* sp. in Japan; and on citrus, *Ficus retusa*, *Morus* sp., *Psidium guajava*, *Vitis vinifera* and a "weed" in Taiwan.

GEOGRAPHIC DISTRIBUTION

Asia: Japan, Okinawa, Taiwan

LIFE HISTORY

No specific life history is available although this mite should be similar to *E. sexmaculatus* which is primarily a pest of the leaf. However it may appear on the fruit in high population levels.

DETECTION AND IDENTIFICATION

On propagation: any life stage.
On non-propagation: Mites in webbing, in calyx or other cavity in fruit.
Diagnosis: Ehara, 1969.

MOVEMENT AND DISPERSAL

Natural spread: Wind and rain, animals. Wind will blow mites onto neighboring fields.
Man-assisted spread: Nursery stock, movement of equipment in the field.

PEST SIGNIFICANCE

Economic impact: The mite is a leaf feeder and recorded from a varitiey of economic crops. Its impact would be similar to the six-spotted spider mite, (*E. sexmaculatus*).
Detection/Control: Inspection, pesticides

PHYTOSANITARY MEASURES

Treatment: Fumigation.
Other safeguards: Destruction of containers.

REFERENCES:

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PEST DATA SHEET

Tetranychus kanzawai Kishida

IDENTITY

Name: Tetranychus kanzawai Kishida
Synonymy: None
Classification: Acari:Tetranychidae
Common names: Kanzawa Mite, Tea Red Spider Mite, Hawthorn Mite

HOSTS

Apple, pear, citrus, clover, corn, eggplant, grape, hops, peach, soybean, tea, Boehmeria nivea, Cordyline terminalis, Capsicum frutescens, Cyathea sp., Ehretia macrophylla, Lychium chiensis, Manihot maritima, M. ultissima, Morus, Murraya paniculata, Perilla frutesscens, Phaseolus lunatus, Prunus campanulata, P. persica, Sambucus, Solanum nigrum, Tecton grandis, Terminalia catappa, Verbenia hortensis, V. phlogiflora. Reported as a key pest of tea, pear, strawberry, mulberry tree, pulse, in Japan.

GEOGRAPHIC DISTRIBUTION

Japan, Korea, Malaysia, Philippines, Taiwan, China, Northern Mariana Islands(?) .

LIFE HISTORY

The biology is taken from the tea plant in Japan. Primarily a pest of the leaf. All life stages may be found throughout the year. The adult female is the diapause form. A grape and bean adapted biotype has also been reported (Kondo et al., 1987).

DETECTION AND IDENTIFICATION

On propagation: any life stage.
On non-propagation: Mites in webbing, in calyx or other cavity in fruit.
Diagnosis: Jeppson et al. (1975).

MOVEMENT AND DISPERSAL

Natural spread: Wind and rain, animals. Wind will blow mites onto neighboring fields.
Man-assisted spread: Nursery stock, movement of equipment in the field.

PEST SIGNIFICANCE

Economic impact: The mite is a leaf feeder and recorded from a varitiey of economic crops. Its impact would be similar to the two-spotted spider mite, (Tetranychus urticae Koch). There appears to be some varietal resistance in tea.
Control: Fruit bagging; pesticides; predators.

PHYTOSANITARY MEASURES

Treatment: Fumigation.

Other safeguards: Destruction of containers.

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PEST DATA SHEET

Parlatoria cinerea Hadden

TAXONOMY
Name: Parlatoria cinerea Hadden
Synonymy: None
Classification: Homoptera:Diaspididae
Common name: Tropical gray chaff scale

HOSTS
Reported on Citrus sp. in Japan. Otherwise reported on Citrus, Mangifera, Bougainvillaea, Rosa, Jasminum, Gardenia, Viburnum, Grewia, Melia, Malus, and Nerium.

GEOGRAPHIC DISTRIBUTION
Brazil, Thailand, Philippines, China, Society Islands, Samoa, Mexico, Indochina, Taiwan, Mexico, Taiwan, Cuba, Dominica, Grenada, Haiti, Jamaica, Montserrat, St. Lucia, Trinidad, Argentina, Suriname, Italy, Spain, Israel, S. Africa, Java, Tahiti, India, New Caledonia, Marquesas Islands, S. Marina Island, Bonin Island, Japan, Guam, Pakistan, Mozambique, Lebanon, Colombia, Cook Island.

LIFE HISTORY
Biology and injury is similar to Parlatoria pergandii Comstock. There are 3-4 generations per year. In Israel, P. dominates in the summer and P. cinerea dominates in the winter.

DETECTION AND IDENTIFICATION
On propagation: any life stage.
On non-propagation: any life stage.
Diagnosis: McKenzie, 1945.

MOVEMENT AND DISPERSAL
Natural spread: immatures (crawlers), animals, or by wind.
Man-assisted spread: Nursery stock.

PEST SIGNIFICANCE
Economic impact: May reduce plant vigor, cosmetic damage to fruit and additional costs due to control measures.
Detection/Control: Inspection, pesticides

PHYTOSANITARY MEASURES
Treatment: on fruit none, (See USDA, 1985) otherwise Fumigation.
Other safeguards: None indicated.

REFERENCES

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McKenzie, H. L. 1945. A revision of Parlatoria and closely allied genera (Homoptera: Coccoidea: Diaspididae). Microentomol. 10:47-121.

USDA, 1985. Pest Risk Assessment of Armored Scales on Certain Fruit. 33pp.

PEST DATA SHEET

Planococcus lilacinus (Cockerell)

IDENTITY

Name: Planococcus lilacinus (Cockerell)

Synonymy: Dactylopius crotonis Green, Planococcus citri (Risso) Ferris [Misidentification], P. crotonis (Green) Ferris, P. lilacinus (Cockerell) Ferris, P. tayabanus (Cockerell) Ferris, Pseudococcus lilacinus Cockerell, P. tayabanus Cockerell, P. crotonis (Green) Sasscer, P. deceptor Betrem, Tylococcus mauritiensis Mamet,

Classification: Homoptera:Pseudococcidae

HOSTS

Anacardiaceae: Mangifera indica; Annonaceae: Annona sp., Cananga oderata; Asteraceae: Adenophyllum sp.; Bombaceae: Ochroma sp.; Dioscoreaceae: Dioscorea sp.; Dipterocarpaceae: Dipterocarpus sp.; Ehretiaceae: Cordia myxa; Euphorbiaceae: Codiaeum sp., C. variegatum, Euphorbia pyrifolia, Mallotus japonicus; Guttiferae: Calophyllum inophyllum; Iridaceae: Gladiolus carmels; Lecythidaceae: Couroupita guianensis; Legumonosae: Albizia lebbeck, Arachis hypogea, Bauhinia monandra, Cajanus sp., Erythrina lithosperma, E. indica, E. variegata, Hymenaea sp., Pongamia pinnata, Prosopis juliflora, Tamarindus indica; Malvaceae: Hibiscus rosa-sinensis; Moraceae: Castilloa elastica, Ficus rubra; Myrtaceae: Eugenia mespiloides, Psidium guajava; Palmae: Cocos nucifera, Phoenix dactylifera; Pandaceae: Pandanus sp.; Puniaceae: Punica granatum; Rhamnaceae: Alphitonia incana, Zizyphus jujuba; Rubiaceae: Coffea canephora, C. sepahijala; Rutaceae: Citrus aurantium, C. grandis; Sapindaceae: Litchi sp.; Simaroubaceae: Ailanthus sp.; Solanaceae: Nicotiana tabacum; Sterculiaceae: Theobroma cacao; Umbelliferae: Apium graveolens; Verbenaceae: Tectona grandis; Vitidaceae: Viotis vinifera.

GEOGRAPHIC DISTRIBUTION

Aden, Bangladesh, Borneo, Burma, Cambodia, Cocos Keeling Island, China, Comoros, Dominican Republic, El Salvador, Guyana, Haiti, India, Indonesia, Japan, Java, Madagascar, Mauritius, Papua New Guinea, Philippines, Rodriguez Island, Seychelles, Sri Lanka, Taiwan, Thailand, Vietnam, West Malayasia

LIFE HISTORY

Biology, natural enemies and hostplants of this insect are described by Le Pelley (1943, 1968).

DETECTION AND IDENTIFICATION

Morphology: Cox (1989), Williams and Granara de Willink (1992).

MOVEMENT AND DISPERSAL

Natural spread: Local dispersion by alates; possible long distance distribution due to wind.

Man-assisted spread: Adults and nymphs possible on fruit and on propagative material. This insect is strongly attracted to the color yellow. Therefore the possibility exists for this insect being introduced with/on yellow packaging or aircraft parts.

PEST SIGNIFICANCE

Economic impact: Planococcus lilacinus is a pest of cocoa throughout the Oriental Region as well as a number of economically important crops such as citrus, coffee, custard apple, guava and mango (Cox, 1989).

Control: Insecticide applications, biological control agents and resistant varieties.

PHYTOSANITARY MEASURES

Inspection and treatment.

LITERATURE CITED

Cox, J. M. 1989. The mealybug genus Planococcus (Homoptera:Pseudococcidae). Bull. Br. Mus. Nat. Hist. (Ent.) 58:1-78.

Le Pelley. R. H. 1943. An Oriental mealybug (Pseudococcus lilacinus Ckll.)(Hemiptera) and its insect enemies. Trans. Royal Entomol. Soc. London 93:73-93

---. 1968. Pests of coffee. London and Harlow, Longmans, Green & Co., Ltd. 590pp.

Williams, D. J. and M. C. Granara de Willink. 1992. Mealybugs of Central and South America. CAB International, Wallingford. 635 pp.

Gary L. Cave
March, 1995

PEST DATA SHEET

Planococcus kraunhiae (Kuwana)

IDENTITY
Name: Planococcus kraunhiae (Kuwana)
Synonymy: Dactylopius kraunhiae Kuwana, Planococcus kraunhiae (Kuwana) Ferris, P. siakwanensis Borchsenius, Pseudococcus kraunhiae (Kuwana) Fernald
Classification: Homoptera:Pseudococcidae

HOSTS
Ebenaceae: Diospyros kaki; Leguminosae: Wisteria floribunda; Pittosporaceae: Pittosporum tobira; Platanaceae: Platanus orientalis; Rosaceae: Pyrus serotina; Rutaceae: Citrus spp.; Vitaceae:
Vitis vinifera.
Also recorded from Wisteria floribunda (as Kraunhia floribunda)(Kuwana, 1902), Ficus carica (Moraceae), Plantanus orientalis (Plantanaceae), Citrus noblis var. unshiu, C. paradisi, and Ilex sp. (Aquifoliaceae)(McKenzie, 1967). Some of these records may be based on misidentifications (Cox, 1989). The records by Ezzat & McConnell (1956) on Croton sp. from Jamaica and Olea chrysophylla from Eritrea, Ethiopia are dubious. Specxijmens of the latter record have been located and are a species of Delottococcus (Cox, 1989).

GEOGRAPHIC DISTRIBUTION
China, Japan, Korea

LIFE HISTORY
Planococcus kraunhiae is normally found thgree times a year in the western Japanese regions such as Ehime and Wakayama Prefectures; and 2-3 times a year in Shizouka Prefecture. The first, second and third generations are usually found from May-July, July-October and October to May, respectively. In late March, the nymphs leave their overwintering sites and begin to move along the shoots and locate around the buds (Country Packet for Japan - Unshu Orange, USDA, 1994)

DETECTION AND IDENTIFICATION
Morphology: Cox (1989), Williams and Granara de Willink (1992).

MOVEMENT AND DISPERSAL
Natural spread: Local dispersion by alates; possible long distance distribution due to wind.
Man-assisted spread: Adults and nymphs possible on fruit and on propagative material. This insect is strongly attracted to the color yellow. Therefore the possibility exists for this insect

being introduced with/on yellow packaging or aircraft parts.

PEST SIGNIFICANCE

Economic impact: Planococcus lilacinus is a pest of cocoa throughout the Oriental Region as well as a number of economically important crops such as citrus, coffee, custard apple, guava and mango (Cox, 1989).

Control: Insecticide applications, biological control agents and resistant varieties.

PHYTOSANITARY MEASURES

Inspection and treatment.

LITERATURE CITED

Cox, J. M. 1989. The mealybug genus Planococcus (Homoptera:Pseudococcidae). Bull. Br. Mus. Nat. Hist. (Ent.) 58:1-78.

Ezzat, Y. M. and H. S. McConnell. 1956. A classification of the mealybug tribe Planococcini (Pseudococcidae, Homoptera). Bull. Univ. Maryland Agric. Exp. Sta. A-84:1-108.

Kuwana, S. I. 1902. Coccidae (scale insects) of Japan. Proc. Calif. Acad. Sci (3) Zool. 3:43-84.

McKenzie, H. L. 1967. Mealybugs of California with taxonomy, biology and control of North American species (Homoptera: Coccoidea:Pseudococcidae). Berkeley, Los Angeles. 524pp.

PEST DATA SHEET

Pseudococcus cryptus Hempel

IDENTITY

Name: *Pseudococcus cryptus* Hempel

Synonymy: *Planococcus cryptus* Hempel, *Pseudococcus citriculus* Green, *P. comstocki* (Kuwana).

Classification: Homoptera:Pseudococcidae

HOSTS

Citrus spp. are the principal hosts. However, this insect has been reported on *Cocos nucifera*, Poaceae, (Williams and Granara de Willink, 1992), avocado, annona, guava, mango, white sapote and jambolan (Avidov and Harpaz, 1969). A number of laboratory hosts are listed by Avidov and Harpaz (1969).

GEOGRAPHIC DISTRIBUTION

Asia: China, Japan, Sri Lanka.

North America (USA): Hawaii, Virgin Islands.

South America: Argentina, Brazil, El Salvador, Paraguay.

LIFE HISTORY

Summer females have a preoviposition period of one to two days, while this period may last for as long as one month for Winter females. Mated females then oviposit 200-500 eggs. Nymphal eclosion occurs in 2-14 days, and maturation takes 35-125 days. In Israel, there may be six generations per year (Avidov and Harpaz, 1969).

DETECTION AND IDENTIFICATION

Morphology: Avidov and Harpaz (1969); Williams and Granara de Willink (1992).

NOTE

Considerable confusion exists over the identifcation of this insect. For a more complete discussion see Avidov and Harpaz (1969); Williams and Watson (1988) and Williams and Granara de Willink (1992).

MOVEMENT AND DISPERSAL

Natural spread: Adults and nymphs under their own locomotion.

Artificial spread: Movement of infested plant materials.

PEST SIGNIFICANCE

Economic impact: All parts of the citrus tree from the root to the fruit at attacked by this mealybug (Avidov and Harpaz, 1969). Ben-Dov (1988) discusses the pest status of this insect in Israel.

PHYTOSANITARY MEASURES

Treatment: Fumigation.

LITERATURE CITED

Avidov, Z. and I. Harpaz. 1969. Plant Pests of Israel. Israel Universities Press, Jerusalem. 549 pp.

Ben-Dov, Y. 1988. The scale insects (Homoptera: Coccoidea) of citrus in Israel: diversity and pest status. pp. 1075-1082 in Goren, R. and K. Mendel [eds.] Proceedings of the Sixth International Citrus Congress, Tel Aviv, Israel. Philadelpia/Rehovot, Balaban Publishers.

Williams, D. J. and M. C. Granara de Willink. 1992. Mealybugs of Central and South America. CAB International, Wallingford. 635 pp.

---, and G. W. Watson. 1988. The Scale Insects of the Tropical South Pacific Region, Part 2, The Mealybugs (Pseudocodccidae). CAB International, Wallingford. 260 pp.

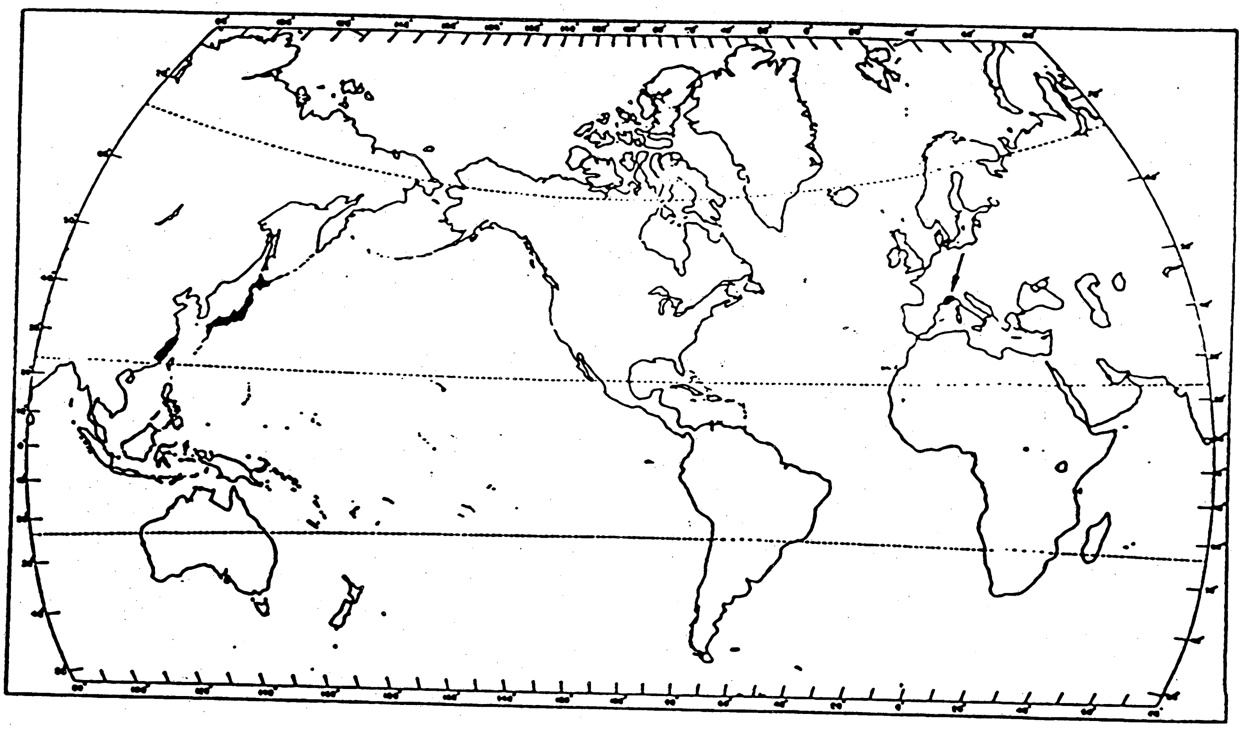
INSECTS NOT KNOWN TO OCCUR IN THE UNITED STATES

ARROWHEAD SCALE (Unaspis yanonensis (Kuwana))

Economic Importance: The species, also called yanone scale, is one of the most injurious scale insects of citrus in Japan. Many trees have been killed by it in the Nagasaki area of Japan and large parts of infested groves have been seriously infested. Even at a distance, infested trees may be recognized because of the large masses of white male cocoons on the foliage. Females are usually seen on the twigs and small branches as well as the fruit. Although the scale was described in Chionaspis in 1923, it was known in Prontaspis from that year until 1949.

Distribution: China (citrus areas of the southeast mainland), France (Côte d'Azur), and Japan.

Hosts: Many species of citrus.



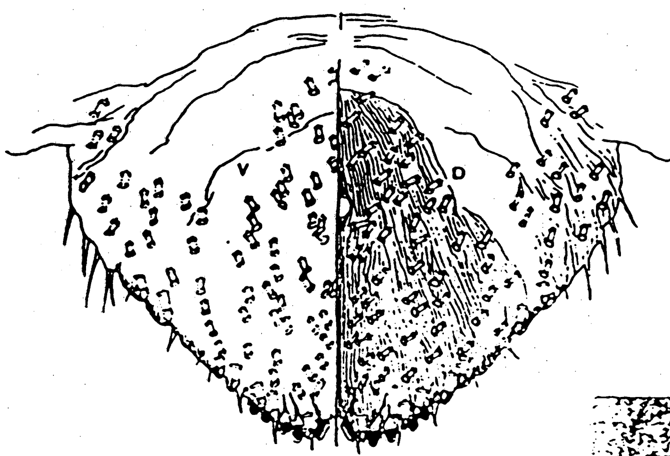
General Distribution of Unaspis yanonensis (Kuwana)

Life History and Habits: Under conditions in Japan, females and sometimes ma'e pupae have been known to hibernate. Females are ovoviviparous and each may .o-duce about 140 nymphs in the first generation, 170 in the second and 40 in the third. The nymphs of the first generation appear about mid-May in the north and a second nymphal peak takes place about 10-15 days later. In southern Japan, nymphs of the first generation occur approximately one month earlier. At temperatures of 68° F., development of first stage nymphs requires nearly 25 days and the second stage about 18 days. First generation nymphs may be found up to August, whereas those of the second and third are present almost to November. Three generations a year occur in Japan.

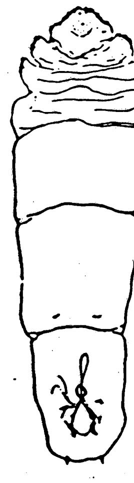
Hemiptera: Diaspididae

No. 176 of Series

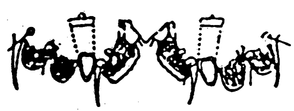
Description: ADULT - Female scale cover - Length 2.84-3.56 mm. Elongate, darkish brown with a gray margin, exuviae pale yellow. Sides slope away from central ridge. Body - Elongate with distinct segments; heavily chitinized. Pygidium - Large, with three pairs of well developed lobes; median lobes also largest and slightly sunken into pygidium. Anus circular, closer to base than apex of pygidium. Dorsal gland orifices numerous and variable in number. Male scale cover - Length about 1 mm. Elongate with sides nearly parallel, white and with three ridges.



Pygidium of Female



Female



Margin of Pygidium

Heavily Infested Orange
USDA Photo

Selected References: 1. Clausen, C. P. 1927. U.S. Dept. Agr. Tech. Bul. 15, 15 pp. 2. Kuwana, I. 1926. The Diaspine Coccidae of Japan, IV. Jap. Imperial Plant Quar. Serv. Tech. Bul. 4, 44 pp. 3. Nakayama, S. 1968. Personal communication. 4. Nishino, M., Furuhashi, K. and Matsunaga, Y. 1965. Shizuoka Pref. Citrus Expt. Sta. Bul. 5:69-93. 5. Ohgushi, R. and Nishino, T. 1966. Jap. J. Appl. Ent. and Zool. 10(1):7-16. 6. Takezawa, H. and Aihara, J. 1962. Jap. J. Appl. Ent. and Zool. 6(3):208-215.

Illustrations of female and pygidium from Kuwana

Prepared in Survey and Detection
Operations in cooperation with other
ARS agencies.

U.S. Dept. Agr.
Coop. Econ. Ins. Rpt.
18(17):349-350, 1968

PEST DATA SHEET

Toxoptera citricida (Kirkaldy)
Brown Citrus Aphid

IDENTITY

Name: Toxoptera citricida (Kirkaldy)

Synonymy: Aphis aeglis Shinji, A. citricida (Kirkaldy), A. aphoides van der Goot, A. nigricans van der Goot, A. tavaresi Del Guercio, Myzus citricidus Kirkaldy, Paratoxoptera argentinensis Blanchard.

Classification: Homoptera:Aphididae

Common names: Braune Citrusblattlaus, Brown Citrus Aphid, Oriental Black Citrus Aphid, Puceron tropical de l'oranger, Pulgon cafe de los citros, Tropical Citrus Aphid.

HOSTS

Limited largely to Rutaceae, especially Citrus (Stoetzel, 1990).

GEOGRAPHIC DISTRIBUTION

Africa: Cameroon, Congo, Ghana, Kenya, Mauritius, Mozambique, Nigeria, Reunion, Senegal, Sierra Leone, South Africa, St. Helena, Sudan, Tanzania, Uganda, Zimbabwe.

Asia: China, India, Indonesia, Japan, Korea, Malaysia, Philippines, Sri Lanka, Taiwan, Thailand.

Oceania: Australia, Cook Islands, Fiji, New Zealand, Tasmania.

Central America: Costa Rica, El Salvador, Nicaragua, Panama.

North America (USA): Hawaii, Puerto Rico.

South America: Argentina, Brazil, Chile, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.

West Indies: Cuba, Dominica, Dominican Republic, Guadeloupe, Jamaica, Martinique, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago.

NOTE

Toxoptera citricida (Kirkaldy) and Toxoptera aurantii (Boyer de Fonscolombe) have often been confused. Many records applying to T. aurantii actually refer to T. citricida (EPPO, 1979).

LIFE HISTORY

Females of this insect are parthenogenic, one generation being completed in 6 - 12 days (EPPO, 1979; INKTO). This species is anholocyclic, sexual forms are not known in nature (Carver, 1978). This species thrives in moist, warm climates and appears to tolerate colder conditions than its congener, Toxoptera aurantii (Blackman and Eastop, 1984). Reproductive potential is dependent upon the quality of the host plant. This ranges from 47 nymphs produced in 12 days to 22 nymphs produced in 20 days (EPPO, 1979). Adults and nymphs feed on young, soft tissues of buds, leaves, stems (Carver, 1978) and sometimes young fruit (EPPO, 1992). Alate flight has been correlated with rainfall.

Gary L. Cave
September, 1994

And, it has been reported that populations are higher after seasons with high summer rainfall, due possibly to increased shoot growth available to the aphids during the winter (EPPO, 1992).

DETECTION AND IDENTIFICATION

Morphology

Denmark, 1978; Doncaster and Eastop, 1956; Stroyan, 1961; Blackman and Eastop, 1984; Stoetzel, 1990.

MOVEMENT AND DISPERSAL

Natural spread: Local dispersion by alates; possible long distance distribution due to wind.

Man-assisted spread: Adults and nymphs possible on fruit and on propagative material. This insect is strongly attracted to the color yellow. Therefore the possibility exists for this insect being introduced with/on yellow packaging or aircraft parts.

PEST SIGNIFICANCE

Economic impact: The most efficient vector of citrus tristeza virus, this insect has also been reported to vector citrus vein enation virus, Citrus yellows virus, Citrus stem pitting virus, Citrus dwarf virus, Eureka seedling virus and bud union decline of lemon and orange (Brown _et_. _al_., 1988; Costa and Grant, 1951; EPPO, 1979; McClean, 1975). This insect is also able to transmit mosaic viruses of abaca, pea and yam (Blackman and Eastop, 1984) and chili veinal mottle virus (Blackman and Eastop, 1984; EPPO, 1979). Concomitantly, the production of large amounts of honeydew by the aphids causes sooty mold formation on leaves and fruit. Thus reducing the marketability of the fruit.

Control: Insecticide applications, biological control agents and resistant varieties.

PHYTOSANITARY MEASURES

Prohibit the importation of plants for propagation and cut branches of host plants where this insect is known to occur. This is especially important for those areas where this insect and citrus tristeza coexist.

LITERATURE CITED

Blackman, R. L. and V. F. Eastop. 1984. Aphids on the World's Crops: An Identification Guide. John Wiley & Sons, Chichester, New York, Brisbane,Toronto, Singapore. 466 pp.

Brown, L. G., Denmark, H. A. and R. K. Yokomi. 1988. Citrus tristeza virus and its vectors in Florida. Plant Pathol. Circ. 311, Fla. Dept. Agric. Consum. Serv., Div. Plant Indus. 2 pp.

Carver, M. 1978. The black citrus aphids, _Toxoptera_ _citricidus_ Kirkaldy) and _T_. _aurantii_ (Boyer de Fonscolombe) (Homoptera:Aphididae). J. Aust. Entomol. Soc. 17:263-70.

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McClean, A. P. D. 1975. Tristeza virus complex: its transmission by the aphid Toxoptera citricidus. Phytophylactica 7:109-13.

Stoetzel, M. B. 1990. Some aphids of importance to the southeastern United States (Homoptera:Aphididae). Fla. Entomol. 73:580-86.

Stroyan, H. L. G. 1961. Identification of aphids living on Citrus. FAO Plant Protect. Bull. 9:45-65.

Gary L. Cave
November, 1994

Entomology Circular No. 180
July 1977

Fla. Dept. Agric. & Consumer Serv.
Division of Plant Industry

THE ASIATIC CITRUS PSYLLID, DIAPHORINA CITRI KUWAYAMA (HOMOPTERA:PSYLLIDAE)[1]

Frank W. Mead[2]

INTRODUCTION: The Asiatic or oriental citrus psyllid, Diaphorina citri Kuwayama, is widely distributed in southern Asia. It is an important pest of citrus in several countries, particularly India, where there has been a serious decline of citrus in recent years. This psyllid does not occur in North America or Hawaii but was reported in Brazil, by Costa Lima (1942; Rio de Janeiro) and Catling (1970). D. citri often has been referred to as "citrus psylla," but this is the same common name often applied to Trioza erytreae (Del Guercio), the psyllid pest of citrus in Africa. T. erytreae, to avoid confusion, should be referred to as the African citrus psyllid or the twospotted citrus psyllid (the latter name in reference to a pair of spots on the base of the abdomen in late stage nymphs). These 2 psyllids are the only known vectors of the etiologic agent of citrus greening disease and are the only economic species on citrus in the world. Three other species of Diaphorina have been reported on citrus (2 in Swaziland, 1 in India), but these are non-vector species of relatively little importance.

DESCRIPTION AND IDENTIFICATION: ADULTS (fig. 1) 3-4 mm long; body brown mottled; head light brown (black in Trioza erytreae); forewing broadest apical half, mottled, and with brown band extending around periphery of outer half of wing, the band slightly interrupted near apex (broadest at middle, unspotted, and transparent in T. erytreae); antennae with black tip and 2 small light brown spots on middle segments (nearly all black in T. erytreae); living insect covered with whitish, waxy secretion, making it appear dusty. NYMPHS (fig. 1) 0.25 mm long in 1st instar, 1.5-1.7 mm in last (5th) instar; color generally yellowish orange; no abdominal spots (advanced nymphs of T. erytreae with 2 basal dark abdominal spots); wing pads massive (small pads in T. erytreae); large filaments confined to apical plate of abdomen (T. erytreae with fringe of fine white filaments around whole body, including head). EGGS (fig. 1) approximately 0.3 mm long, elongate, almond-shaped, thicker at base, and tapering toward distal end; fresh eggs pale, but then turning yellow and finally orange at time of hatching; eggs placed on plant tissue with long axis vertical to surface (long axis horizontal to surface in T. erytreae).

Identifications having regulatory significance should be made by taxonomists with adequate reference materials. Psyllids as a group are most likely to be confused with aphids. Aphids are common on tender citrus leaves; aphids are sluggish but adult psyllids are active jumping insects; aphids usually have 4-6 segmented antennae, while psyllids usually have 10; most aphids have cornicles on the abdomen, which the psyllids lack. *Any psyllid colony found on citrus in the United States should be viewed with alarm and emergency action taken.*

DAMAGE: Injury caused by the psyllids results from the withdrawal of large quantities of sap from the foliage, heavy development of sooty mold on honeydew-covered leaves, and transmission of the organism that causes greening disease. The once flourishing citrus industry in India is slowly being wiped out by dieback. This dieback has multiple causes but primarily it is due to greening disease. What is now generally accepted as greening disease has been called citrus chlorosis in Java, leaf-mottling and leaf-mottle yellows in the Philippines, likubin in Taiwan, and

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2/ Taxonomic Entomologist, Div. Plant Ind., P. O. Box 1269, Gainesville, FL 32602.

yellow shoot in China.

CONTROL: Many workers in India have reported that D. citri can be controlled effectively with a wide range of modern insecticides. Bindra et al. (1974) reported that for overall effectiveness against nymphs and adults at different intervals after spraying, the chemicals monocrotophos, dimethoate, fenitrothion, fenthion, and endosulfan (0.05% each) were effective. Several other chemicals, including methyl demeton were promising. They wrote that dimethoate was preferable because it was less expensive and has a lower dermal toxicity with the exception of fenitrothion. Dimethoate, being a systemic insecticide, does less damage to non-target fauna and could prove fatal even to the nymphs and adults of the Asiatic citrus psyllid that escape direct spraying. Injection of trees with tetracycline antibiotics to control greening disease has been effective where the vector can be kept under control. A more lasting effect was obtained by injecting trees with a "new" chemotherapeutant produced in India called B.P.-101. In countries where greening has spread over long distances, it has occurred because of the movement of infected and infested nursery stock; only clean and healthy plants should be transported. In areas of low incidence of greening, the relatively few infected trees should be removed to prevent them from being reservoirs of the pathogen. Tests in India by Raychaudhuri et al. (1974) showed that the greening organism of infected budwood could be deactivated by either hot (moist) air, hot water, or 21 days in the heat therapy chamber.

Natural enemies of D. citri include syrphids, chrysopids, at least 12 species of coccinellids, and several species of chalcidoids, the most important of which is Tetrastichus radiatus Waterston.

HOSTS: Mainly Citrus spp., at least 2 species of Murraya, and at least 3 other genera all in Rutaceae.

LIFE HISTORY: Eggs are laid on tips of growing shoots on and between unfurling leaves. Females may lay more than 800 eggs during their lives. Nymphs pass through 5 instars. Total life cycle requires from 15 to 47 days, depending upon the season. Adults may live for several months. There is no diapause but populations are low in winter (the dry season). There are 9 to 10 generations a year; 16 have been observed in field cages. Numerous papers have appeared containing life history information, among them the following: Atwal et al. (1970), Capoor et al. (1974), Catling (1970), Husain & Nath (1927), Mangat (1961), Mathur (1975), Pande (1971), USDA, ARS (1959), and Wooler et al. (1974).

DISTRIBUTION: D. citri ranges primarily in tropical and subtropical Asia and has been reported from the following geographical areas: China, India, Burma, Taiwan, Philippine Islands, Malaysia, Indonesia, Ceylon, Pakistan, Thailand, Nepal, Sikkim, Hong Kong, Ryukyu Islands, Afganistan, Saudi Arabia, Réunion, Mauritius, and Brazil. The discovery of D. citri in Saudi Arabia (Wooler et al., 1974) is the first record from the Near East. T. erytreae also occurs in Saudi Arabia, preferring the eastern and highland areas where the extremes of climate are present, whereas D. citri is widespread in the western, more equitable coastal areas.

SURVEY AND DETECTION NOTES: Sooty mold on foliage indicates presence of Homoptera. Ground under heavily infested citrus may appear white from honeydew deposits. NYMPHS, which are always found on new growth, move in a slow, steady manner when disturbed. The ADULTS leap when disturbed and may fly a short distance. They are usually found in large numbers on the lower sides of the leaves with heads almost touching the surface and the body raised almost to a 30 degree angle. The period of greatest activity of the psyllid corresponds with the periods of new growth of citrus. There are no galls or pits formed on the leaves as caused by many other kinds of psyllids; the nymphs are completely exposed (the nymphs of T. erytreae are partially enclosed in a pit). Citrus trees in advanced stages of decline are somewhat similar to those affected by tristeza. Field recognition of greening in Asia from symptoms alone is often difficult. Very similar leaf symptoms may be caused by a wide variety of factors varying from nutritional disorders to the presence of other diseases such as root rots and gummosis, tristeza, and exocortis. Capoor et al. (1974) described GREENING SYMPTOMS of citrus as trees showing stunted growth, sparsely foliated branches, unseasonal bloom, leaf and fruit drop, and twig dieback. Young leaves are chlorotic, with green banding along the major veins. Mature leaves have yellowish-green patches between veins, and midribs are yellow. In severe cases, leaves become chlorotic and have scattered spots of green. Fruits on greened trees are small, generally lopsided, underdeveloped, unevenly colored, hard, and poor in juice. The columella was found to be almost always curved in sweet orange fruits and apparently the most reliable diagnostic symptom of greening. Most seeds in diseased fruits are small and dark colored. Schwarz et al. (1974) listed 4 reasons why the symptoms of greening in Southeast Asia were often different from those in South Africa. These reasons included the more tropical climate of Asia keeping mature fruit green, citrus variety differences, differences in the heat tolerance of the vectors leading to different disease distribution in the grove, and differences in the virulence of the strains of the pathogen.

TRANSMISSION: Capoor et al. (1974) reported a high percentage of transmission by tissue grafts. They found that 4th and 5th instar nymphs and adults could effect transmission. *D. citri* requires an incubation period of about 21 days in which to transmit the pathogen, which it retains for life following a short access feeding (15-30 minutes) on a diseased plant. It is unnecessary for adult psyllids arising from infectious nymphs to have access feeding on diseased shoots in order to become vectors. Adult psyllids were able to transmit greening in a minimum infection feeding of 15 minutes but the percentage of transmission was low. One hundred percent infection was obtained when the psyllids fed for 1 hour or more. Capoor et al. (1974) strongly indicated that the pathogen multiplied in the body of the psyllid and that there was an absence of transovarial transmission. They summarized differences between *D. citri* and *Trioza erytreae* in various aspects of greening transmission. Moll and van Vuuren (1977, p. 38) concluded that the greening causal agent most closely resembles a gram-negative bacterium under the electron microscope. They designated the pathogen as a bacterium-like organism.

QUARANTINE SUMMARY:
Florida Department of Agriculture Rules (provide legal basis for excluding citrus, except fruit, from entering Florida):

1. Plants, General, Chapter 5B-1.
2. Transit Inspection, Chapter 5B-4.
3. Fruit Flies and Other Dangerous Diseases, Chapter 5B-8.
4. Spiny Citrus Whitefly or Blackfly, Chapter 5B-9.
5. Citrus Canker and Other Citrus Diseases, 5B-10.

Federal Foreign Quarantine No. 19, Citrus Canker and Other Citrus Diseases (provides legal basis for excluding citrus, except fruit, from entering U.S.A.).

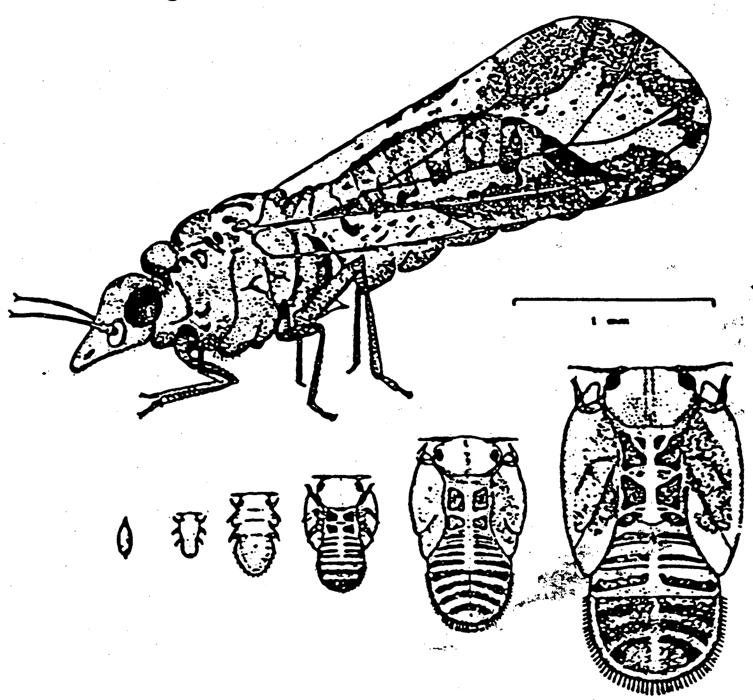

Fig. 1.
Egg, 5 nymphal instars and adult female of *Diaphorina citri* Kuwayama (from Catling, H. D. 1970).

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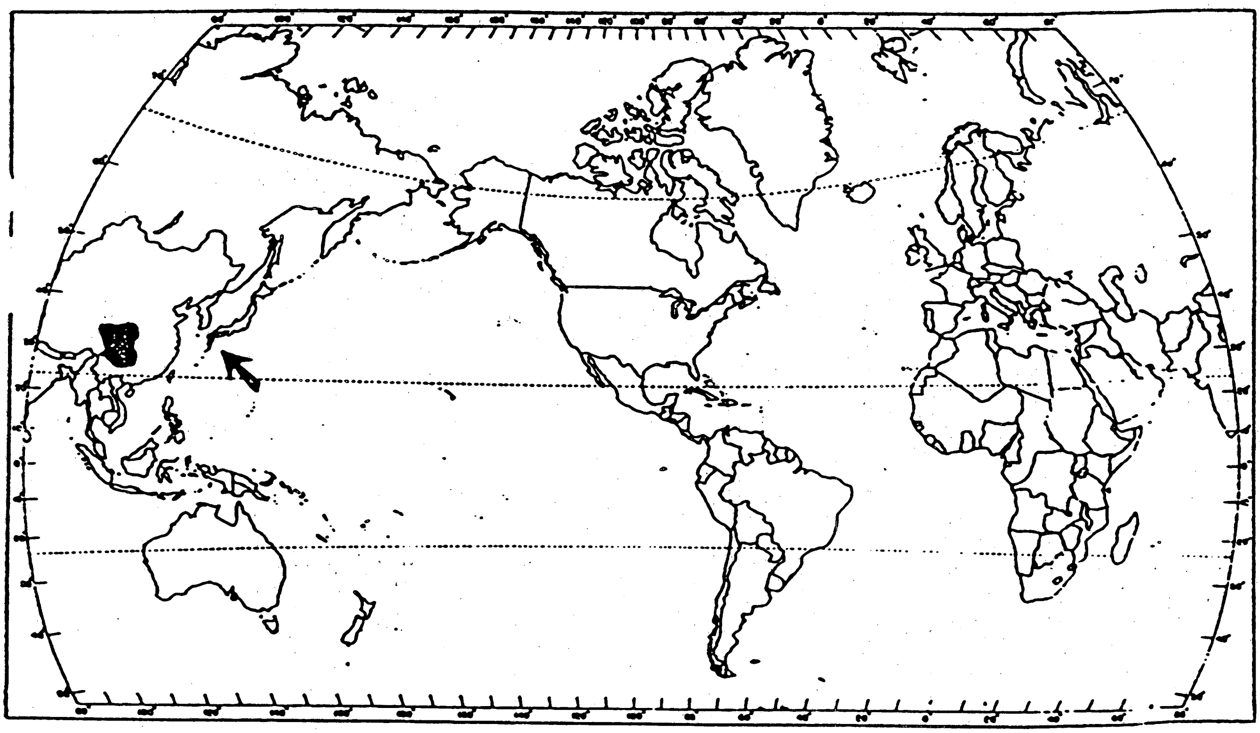
INSECTS NOT KNOWN TO OCCUR IN THE UNITED STATES

JAPANESE ORANGE FLY (Dacus tsuneonis Miyake)

Economic Importance: This tephritid, described by Tsunekata Miyake in 1919, is one of the most important pests of citrus in Japan. In that country, it is found only in Kyushu and on Amami-O-shima Island. Extensive outbreaks have occurred in some commercial citrus areas since 1947 when up to 60 percent or more of the fruits were infested. In Szechwan Province of southwestern China, the fruit fly has also been reported to have infested 50 percent of the oranges at Kiangtsin during 1940.

Distribution: Japan (Kyushu and Amami-O-shima Island) and southwestern China (Szechwan and Kweichow Provinces).

Hosts: Citrus, including orange, grapefruit and mandarin orange.



General Distribution of Dacus tsuneonis Miyake

Life History and Habits: The biology as studied in Japan is as follows: Adult emergence dates vary from place to place, but detailed studies show that the emergence period covers about 50 days from the beginning of June to the middle of July. They are occasionally found as late as October, however. The length of the preoviposition period of the adults reared under field laboratory conditions was between 17 and 25 days. The ratio of males to females was one to one. It appears that copulation is of frequent necessity with the females that are freely ovipositing, and copulation probably takes place after depositing each batch of eggs. The adults feed on honeydew excreted by various species of aphids, coccids and psyllids, which appears necessary for health, longevity and

(Tephritidae, Diptera)

egg production, during the preoviposition period. Flies are usually found in shady, thickly wooded places. Eggs are laid under the rind, with thick-skinned fruit being seldom attacked. A single puncture is usually made in each infested fruit. Although frequently 2-8 eggs may be found in each puncture, only one larva emerges from the puncture. Larvae appear about the first of October and devour the contents of one carpel after another, from 2-10 carpels being infested by a single maggot. The larva is mature by the beginning of November and usually the infested fruit falls to the ground. The larva leaves the fruit and enters the ground for pupation within a few hours after the fruit drops. Occasionally the larva leaves the fruit on the tree. Pupation occurs 1-2 inches in the soil.

Description: ADULTS - Conspicuously large; female 11 mm. long (excluding ovipositor) and wing expanse 10 mm.; male slightly smaller. Head yellow or ochraceous; ocellar triangle black. Two shiny black, claviform spots on clypeus; a small subtriangular piceous spot in middle of each gena, just below lower margin of eye. Antennae ochraceous, arista piceous, with yellow base. Proboscis with a piceous ridge at base mottled with brown; palpi yellow. Thorax densely punctate, with short, yellowish pubescence, ferrugino-ochraceous; a medium longitudinal, λ-shaped purplish testaceous streak on dorsum, terminating posteriorly in center of the scutum; a pair of rather faint submedian, more or less wavy, purplish testaceous lines, interrupted at transverse suture and united posteriorly with posterior branches of λ-shaped streak; a yellowish patch on each humeral callus; scutellum yellowish, with 2 bristles; median plate of scutellum ochraceous; most of lateral sides of thorax ochraceous. Halteres ochraceous. Legs ochraceous, with yellow pubescence. Wings hyaline, with more or less grayish tinge; veins fusco-ochraceous; area between veins R_1 and R_{4+5} tinged with honey-yellow; radial cell at region above the medial and cubital cells also honey-yellow; a fuscous suffusion at apex of wing; second auxillary lobe wanting in male. Abdomen oval, as broad as thorax, densely punctate, bright ochraceous above, yellowish beneath and brownish at end, with a short, yellowish pubescence; a longitudinal median black, rather broad, streak extends length of abdomen, or almost so; transverse bands present on third, fourth and sometimes the fifth segment, band on the third segment cross-marking longitudinal streak. EGG - Length 1.4 mm.; width 0.3 mm. Creamy white and fusiform in shape, obtusely rounded at one end and rather pointed at the other. Two small elevations on shell at obtuse end. LARVA - Creamy white, with slight yellowish tinge. Length 12-13 mm.; width 3 mm. at broadest part. Body elongated, cylindrical, pointed at anterior apex. Anterior spiracles each with numerous lobes, each provided with an elliptic aperture at tip. Posterior spiracles located dorsally on posterior surface of 12th segment; they appear as paired elliptic chitinous plates, each of which has 3 transverse apertures, the middle one of which is placed slightly external to the others. Each aperture elongate-elliptic, guarded by a chitinous border which bears many inwardly directed fine hairs and shows internally many partitions, owing to presence of some chitinous rods that lie across the aperture. Around each spiracle lie five groups of radiating flat hairs, some of which are branched, each arising from a small, round tubercle. In internally placed groups, hairs appear whirled around their respective tubercles. PUPARIUM - Elliptical, about 10 mm. long and 4 mm. wide, ochraceous in color. (Prepared in Survey and Detec- Operations, in cooperation with other ARS agencies). CEIR 11 (51):12-22-61.

(See page 1124 for illustrations)

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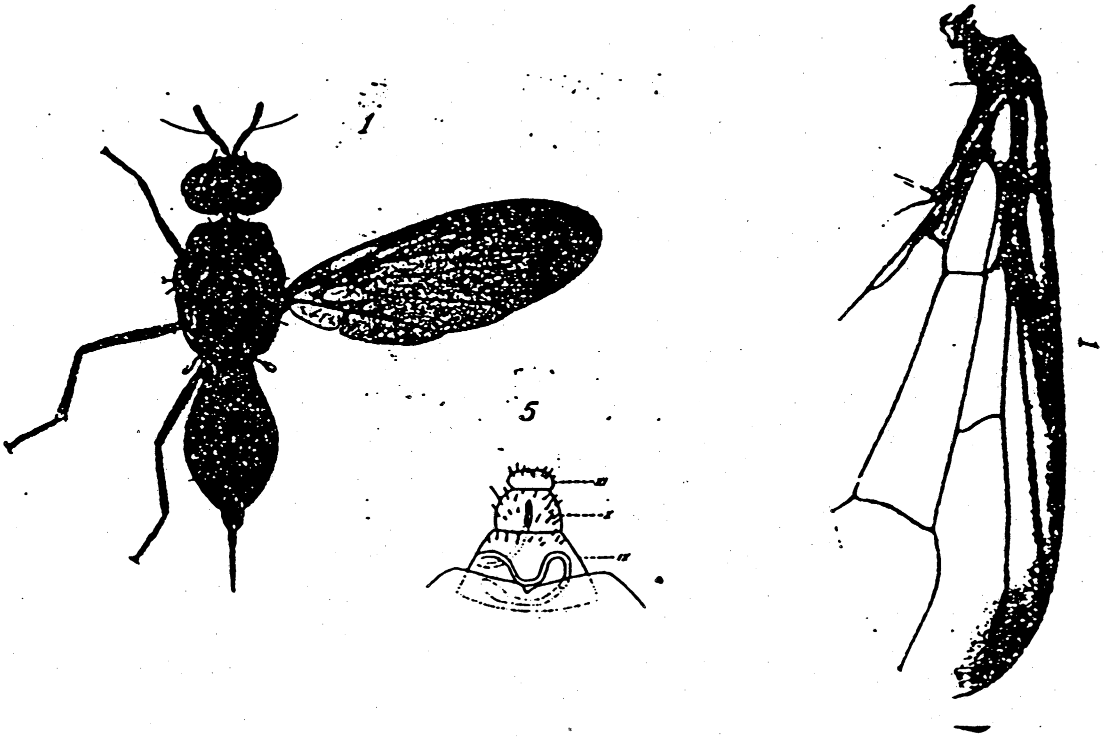
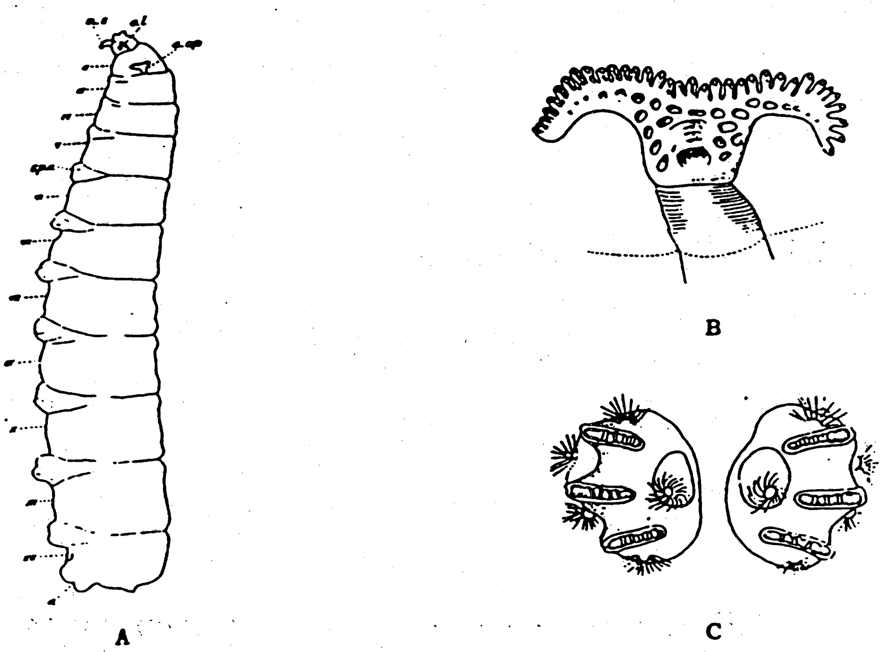


Adult Female and Wing of Dacus tsuneonis Miyake



Larva of D. tsuneonis Miyake (A). Anterior Spiracle (B) and Posterior Spiracles (C)

United States Department of Agriculture
Agricultural Research Service
Beltsville Area
Beltsville Agricultural Research Center
Beltsville, Maryland 20705

October 1, 1985

SUBJECT: Pest Risk Assessment of Armored Scales on Certain Fruit

TO: Charles E. Miller
Staff Specialist
Biological Assessment Support Staff

The attached report is a compilation of the findings and recommendations of our ad hoc working group in response to your memorandum of August 8. Our charge was to assess PPQ's policy of not requiring quarantine action on commercial shipments of certain fruit when found infested with exotic armored scales. We were asked to address armored scales in general and Parlatoria ziziphi (Lucas) and Unaspis yanonensis (Kuwana) specifically.

The enclosed report is divided into four parts. Part 1 is a general discussion of armored scale life history, economic importance, and control as it relates to our charges. Part 2 specifically addresses the areas enumerated in your memorandum. Please note that specific area number 1 in your memorandum has been divided into two separate charges in our report. Part 3 comprises the specific recommendations of the working group. Also note that we have made a recommendation concerning PPQ's policy on imported propagative material as well as on fruit. Part 4 is the results of our search for armored scales that might be of quarantine significance on certain fruit (pome fruit, stone fruit, mango, citrus, and kiwi) and relevant information impinging on quarantine decisions. Fourteen species are included.

The criteria that we used to establish "Consideration status" were: If the species occurs on a range of fruit trees but there is no record of the economic impact of the scale, then these species are designated as "potential pests." If the species occurs on a range of fruit trees and there are records indicating that these species are occasionally of economic importance, then these species are designated as "pests." If the species occurs on a range of fruit trees and there are records indicating that these species are major pests in at least some areas, then these species are designated as "important pests." Hosts that are underlined indicate plants from which the armored scale species is commonly collected.

The list does not include all species that are potential pests on the selected list of fruit.

The attached report is the consensus opinion of members of the working group: Victor L. Blackburn, John A. Davidson, William F. Gimpel, Jr., and Douglass R. Miller (Chairman).

DRM

DOUGLASS R. MILLER
Research Leader
Systematic Entomology Laboratory

Enclosure

cc:
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We believe the primary mission of the Plant Protection and Quarantine Program (PPQ), Animal and Plant Health Inspection Service (APHIS) is to implement the principles of quarantine in order to protect the agricultural interests of the United States from exotic plant pests or potential plant pests. To this end, PPQ has provided written policy to its staff which outlines procedures to perform a pest risk assessment of plant material offered for import. We further believe the pest risk assessment is, or should be, the primary factor used to determine the entry status of plant material offered for shipment or shipped into the United States.

Armored scale insects (Homoptera: Coccoidea: Diaspididae) are highly specialized plant parasites that occur worldwide and attack most plants of economic importance. Some species are restricted to one host, but others are polyphagous. Many of these insects are serious agricultural pests and control measures are often necessary to produce a marketable crop. Accordingly, PPQ should be concerned regarding the possible introduction and establishment of exotic armored scale insects.

Armored scales are so named because they live under a protective wax cover. A typical armored scale insect life cycle usually begins with first generation crawlers appearing in the spring. Soon after emergence the crawlers settle on the host; all above-ground parts of the plant are attacked, including the fruit. They feed on sap through thread-like mouthparts that are inserted into the plant. It is important to note that only crawlers and adult males are mobile; the remaining two female and three male instars lack functional legs. The time required to complete a life cycle can be very short, as in the California red scale which only takes 12 days at 28° C. However, at lower temperatures the developmental period is longer, and with other species one year may be required to complete the life cycle. Adult males are ephemeral, with one pair of obvious wings, and although they fly, they do not feed. The adult females lack wings, do not fly, and are obligate parasites of their host.

Reproduction may be by fusion of gametes from two individuals or by parthenogenesis. Overwintering as eggs or fertilized adult females is common but armored scales occasionally overwinter in other stages. If the imported host material is infested with eggs or fertilized adult females, the probability of establishment is much greater than if immature stages are present. Natural dispersal is accomplished by crawlers under their own locomotion (several meters), on other organisms such as the feet of birds, or by wind. Artificial spread may occur over long distances through movement of infested plant materials.

Control of armored scale insects is difficult. The only predictably susceptible stage to contact insecticides is the crawler, and use of these chemicals requires precise timing during the period when crawlers are present. Spray application timing is complicated by the fact that some species have long crawler emergence periods. Control of armored scale insects during other life history stages can be difficult due to the protection offered by the scale cover. Systemic materials theoretically open the spray window. However, systemics are not effective for scales that feed on the trunk (bark) because these chemicals are transported in the xylem tissue whereas most armored scales feed on the phloem. Systemics do work on the leaves, but not when leaf-feeding scales are in the egg stage or during molts when the insects are not feeding. Oils coat the scale cover, apparently smothering the insect; oils have been used successfully for many years as dormant sprays and recent technology now allows these chemicals to be used as dormant and summer sprays.

Armored scale insects often escape detection at low population levels, even by the trained expert, due to their cryptic nature. Females are small and are concealed under a protective cover that often blends in with the bark of the host plant. Detection is further complicated since many species settle in tight places such as under bark flakes, bud scales, covers, at nodes, or in crotches of the host. Fruit infesting scales usually are hidden around the stem area or in the calyx. Therefore, microscopic examination or host plant dissection may be necessary in order to detect an infestation. Unfortunately, sex pheromones, used so successfully to trap Lepidoptera, have been developed for only a few species of armored scale insects. Therefore, this tool is not available to detect most exotic species accidentally introduced into the U.S.

We have considered the pest risk of armored scale insects as a group and Parlatoria ziziphi (Lucas) and Unaspis yanonensis (Kuwana) specifically. Biological factors such as host plant material, feeding sites, time and duration of growth, developmental stages, methods of reproduction and availability of suitable endemic host material are reviewed. We also considered such factors as the probability of introduction, the establishment of a species, the likelihood of future dispersal or distribution, and current measures available to control armored scales.

PART 2

Charge 1. "Determine the probability in relative terms (very high, high, etc.) of a scale becoming established from infested shipments of commercial fruits."

Our decisions on this charge are based on these criteria: a) the sedentary nature of scale insects and their inability to actively disperse long distances; b) the low probability of establishment because the following conditions must be met: 1) Survival of the rigors of picking and any pre-shipment manipulation; 2) survival of transport to the U.S. (usually under refrigeration); 3) survival of the transfer process and storage at the port of entry; 4) survival of shipment to the market, the marketing process, transport and storage by the consumer, and consumption of the fruit; 5) a susceptible host will be in the near vicinity of the contaminated fruit or fruit part discarded by the consumer; 6) crawlers will be on the discarded imported fruit and will successfully infest the indigenous host, or the contaminated fruit part will remain viable for sufficient time to sustain the imported scale population so that crawlers can be produced and infest the indigenous host; 7) either the population is parthenogenetic or male and female crawlers each successfully infest the indigenous host, develop to adult stages, are synchronously in the appropriate state for mating, successfully locate one another, and produce viable offspring; 8) the climate will be amenable to survival of the founder population throughout the year; 9) the founder population is not exterminated during establishment by any of a multitude of natural or artificial processes; c) fruit usually are not a preferred feeding site of most armored scales and at least some may have reduced survival on this part of the plant compared to those individuals feeding on other parts of the host.

<u>Our conclusion is that armored scales in general have a low probability of establishment from infested shipments of commercial fruit</u>.

Parlatoria ziziphi—Characteristics of this scale that increase the probability of establishment in the U.S. from imported commercial fruit are: a) the species is commonly found on citrus fruit; b) Females produce offspring over a long period of time and most infested fruit will contain most life stages, including the crawler; c) it occurs in geographical areas in the close vicinity to the U.S. and is not treated from some of these areas; d) there may be as many as 7 generations each year.

Characteristics that reduce the probability of introduction are: a) The species has a very restricted host range; b) females produce only a small number of offspring; c) the species apparently requires sexual reproduction.

Based on these criteria, we believe that P. ziziphi has more chance of being established in the U.S. from imported commercial fruit than most armored scales and rate this probability as moderate to low.

Unaspis yanonensis.—Characteristics of this species that increase the probability of establishment in the U.S. from imported commercial fruit are: a) Based on its distribution, it appears that it may be more tolerant of cold than P. ziziphi; b) there are two or three generations each year; c) an individual female may produce as many as 200 eggs; d) because the species overwinters as adult females and this stage occurs for a long period of time, it may be easier for U. yanonensis to start new infestations since the time required from gravid females to crawlers is very short; e) U. yanonensis and U. citri cannot be distinguished by field characteristics; therefore introduction of U. yanonensis might go undetected for sometime because entomologists believed that the newly introduced pest was citrus snow scale.

Characteristics that decrease the probability of establishment in the U.S. from imported commercial fruit are: a) The life history is reasonably well synchronized within populations so that most individuals are in the same stage of development; b) fruit apparently is infested only as a last resort when other parts of the plant are stressed (fruit may be preferred over leaves during the second generation); c) the species has a very limited host range; d) both males and females are required for reproduction; e) citrus from Japan is dipped in chlorine solution for citrus canker. (We do not know what effect this has on the scales, but we doubt if it can be beneficial to their survival.).

Based on these criteria we think that U. yanonensis has approximately the same chance of becoming established in the U.S. from imported commercial fruit as most armored scales and rate this probability as "low."

Charge 2. "Compare the probability of entry and establishment with the pest risk posed by the same pests from fruit in passenger baggage, propagative material entering through inspection stations, and for propagative material being smuggled into the United States."

a) Passenger baggage--It is our understanding that all fruit in this category are confiscated or at least inspected at the port of entry. If this is correct, then appropriate measures are being taken to reduce the risk of this possible avenue of introduction. It is our opinion that armored scale contaminated fruit brought in as passenger baggage poses a greater risk of starting a new infestation in the U.S. because several steps are eliminated that are mentioned in 1 above as necessary for successful establishment, i.e., long-term transport to the U.S. and certain environmental stresses such as cold treatment; transport to the market place and treatment in this situation, etc. However, in our opinion even this mechanism can be given no more than a low to moderate risk factor.

b) Propagative material--We believe this form of plant import to pose the highest risk of armored scale introduction because nearly all steps mentioned in 1 as necessary for successful establishment are eliminated. The most difficult process in starting a new infestation through fruit contamination is the process of host transfer; with propagative material this step is eliminated completely. The infestation on a plant introduced as propagative material, would only undergo the stresses of shipment, marketing, and planting by the consumer. In our opinion, the recent introductions of the armored scales Morganella longispina and Pseudaonidia trilobitiformis most likely occurred through this avenue of founder establishment.

We believe that movement of propagative material from foreign countries to domestic locations poses a high risk of introduction of armored scales. We further believe that inspection of propagative material will not always be effective in detecting low populations of armored scales considering their cryptic nature.

c) Smuggled material--If the items are propagative material, the risk of introduction is as mentioned in 2b but with the added element of no inspection process. The probability of introduction therefore would be higher than for declared items.

Charge 3. "...estimate the general impact on American growers should these pests become established. Would it increase treatment cost significantly or decrease quantity and quality of crops?"

a) First we will discuss armored scales in general, but as you point out, "the impact may have to be addressed at the species level." Armored scales are major pests primarily of perennial plants. They are particularly significant on fruit and nut crops and on ornamentals. Damage usually involves general debilitation of the plant, but such things as toxins have been implicated. Armored scales do not transmit viruses and do not cover the host with honeydew.

Scale insects probably are better controlled by biological control agents than any other group of insect pest. Chemical control is not easily attained, although summer and winter oils, and more traditional contact and systemic insecticides can be useful. Scale insects as part of integrated pest management systems usually can be held below economic levels with the appropriate basic research. Modern monitoring and detection methods allow armored scale populations to be discovered at very small population levels in cases where pheromones have been synthesized.

The committee believes that the introduction of any economically implicated armored scale to the the United States has potential for significant impact on American agriculture. We also believe that it is nearly impossible to predict the impact of a pest when it is introduced into a new area with different climatic conditions, different natural enemies, different host plants, different cultural practices, etc. Because of these circumstances, we emphasize that our estimates of impact are little more than guesses derived from a literature survey of each species.

1) <u>Parlatoria ziziphi</u>--This species has been considered to be a serious pest in certain citrus areas. It causes serious dieback of twigs, deformation of fruit, and it is impossible to remove from the fruit without reducing fruit quality. It has not been implicated as an important pest in recent years and therefore may be susceptible to standard control methods for citrus pests. In our survey, we have been unable to locate a specific natural enemy. All of those recorded in the recent PINKTO (1984) are generalists.

<u>The committee rates the potential general impact of this species as moderate if it should become established in American agriculture.</u>

2) <u>Unaspis yanonensis</u>--This species is considered to be a very serious pest in the areas where it occurs. When it was first discovered in France it apparently was not taken seriously, but after several years control measures were required. In Japan considerable research effort has been devoted to finding effective control measures. Heavy infestations can cause severe damage to both the fruit and foliage of citrus. The aphelinid wasp, <u>Aphytis lignanensis</u> Compere can be used effectively if periodic releases are undertaken.

<u>The committee rates the potential general impact of this pest as high if it should become established into the United States.</u>

PART 3

Charge 4. "Make recommendations on what PPQ's policy should be concerning this problem."

a) We generally concur with the current PPQ philosophy of disallowing all citrus propagative material and foliage into the U.S. and allowing entrance of armored scale infested fruit. The fact that successful establishment of an armored scale imported on fruit would require a very involved series of occurrences makes the likelihood of establishment relatively remote. However, we want to emphasize that it is still possible for such an occurrence to happen. Because of our evaluation of *Unaspis yanonensis* as a high risk pest, we recommend that special measures be taken to alleviate even the remote possibility of establishment. Therefore we recommend that APHIS/PPQ continue procedures of allowing entrance of infested fruit without treatment except for fruit infested with Unaspis yanonensis. In this case, all shipments that are inspected and are determined to be infested should be treated using control measures that will kill armored scales.

b) Although we were not specifically requested to make recommendations about introduced propagative material, we were directed to use propagative material in comparison with fruit as an avenue of scale importation and establishment. Based on our comparison, we are making a second recommendation that concerns propagative materials. We are very concerned that more pest species of armored scales will be introduced in this manner. Because of their cryptic nature, there is a high degree of probability that armored scales will go undetected at ports of entry, particularly when the population level is low. Because many of the processes limiting the probability of establishment from infested fruit do not exist for propagative material, this method of introduction allows a much greater possibility of armored scale establishment. Therefore, we recommend that <u>all propagative material that might be infested with armored scales be treated at the port of entry regardless of armored scale detection. Hosts that might be infested include all perennials and woody ornamentals</u>.

PART 4

The following is an abbreviated list of the species that we believe might be of quarantine significance on the fruit listed in your memorandum. It is not an exhaustive list but probably includes all or at least the majority of the predictably most significant armored scale species. The criteria that we used to establish "Consideration status" were: If the species occurs on a range of fruit trees but there is no record of the economic impact of the scale, then these species are designated as "potential pests." If the species occurs on a range of fruit trees and there are records indicating that these species are occasionally of economic importance, then these species are designated as "pests." If the species occurs on a range of fruit trees and there are records indicating that these species are major pests in at least some areas, then these species are designated as "important pests." Hosts that are underlined indicate plants from which the armored scale species is commonly collected.

Aonidiella comperei McKenzie

Compere scale

Consideration status: Potential pest

Hosts: Annona, Citrus, Vitis, Carica, Cocos 29, Roystonea 31, Musa 114 100, Theobroma 15, Cycas, Barringtonia, Morinda 18, Rosa, Tamarindus 95.

Distribution: India, Micronesia (S. Mariana, Palau, Yap, Caroline Atolls, Truk, Marshall Isl.) 18, Tanganyika 15, Cuba 31, Philippines 111, Taiwan 100, Malaysia 115, China 114, Brazil 95, Dominica, Haiti, Guatemala, Thailand 77, St. Croix 84, USVI, Puerto Rico 85, St. Martin 15, Guadeloupe, Martinique 23.

Slides in coll.: Antiugua, Borneo, Jamaica, Bahamas, Honduras, St. Lucia, Colombia, Dom. Rep., Barbados, Java, Siam, Saipan, Trinidad, Sumatra, Panama, Montserrat, St. Vincent, Strait Settlement, Indonesia, Singapore, Pakistan.

Generations/year:

Location on host: Fruit, leaves, and twigs.

Economic Importance:

Aulacaspis mali Borchsenius

Far East apple scale

Consideration status: Potential pest

Hosts: Crataegus, Humulus, Malus 29, Micromeles 37, Pyrus 36

Distribution: Voroshilov, Siberia 26, South Primorie 37, Sakhalin, Kunashir 36, Primarskii Kraii.35, Japan 58, Tadzhikistan 17

Generations/year: 1, 37.

Location on host: Branches and trunks with thin bark 26.

Economic Importance:

Aulacaspis tubercularis (Newstead)

Consideration status: Potential pest

Hosts: Cinnamomum, Citrus, Laurus, Litsea, Machilus, Mangifera 29, Cocos, Pittosporum, Cucurbita, Luffa, Nephelium 33

Distribution: India, Iraq, Zanzibar, Kenya, Ghana, Rhodesia, South Africa, Mauritius, Java 113, Thailand 2, China, Malaya, New Hebrides, Venezuela 48, Uganda 38, Mozambique 5, Puerto Rico 85, St. Thomas-St. Croix, USVI 84, Philippines 111, Taiwan 97, Brazil 95, Pakistan 1, Colombia 81, El Salvador 22.

Slides in coll. Trinidad, Barbados, Martinique, St. Lucia, Guyana, Guadeloupe, Antigua, Bermuda, Grenada, Dominica, Cuba, San Salvador, Guatemala, Honduras, Mexico, Panama, Dom. Republic, Gambia, Hong Kong, Syria, Tortola, Haiti, St. Vincent, Gabon, Nigeria, Madagascar, Aruba, Guam, Australia.

Generations/year:

Location on host: Leaves, twigs, fruit

Economic Importance:

Chlidaspis prunorum (Borchsenius)

Plum scale

Consideration status: Pest

Hosts: Amygdalus, Armeniaca, Malus 94, Prunus 27, Cydonia 24

Distribution: Iran 94, Armenia, Uzbekistan, Tadzhikistan 27, Turkmen 32, Bulgaria 71

Generations/year: Overwinters as larva 71.

Larvae emerge May 12, male flight begins June 16, females start to oviposit June 30 (In Turkmen) 32

Location on host: Twigs, leaves 14.

Economic Importance: Causes withering of twigs & leaves 14.

Chrysomphalus pinnulifer (Maskell)

Pinnule scale

Consideration status: Important pest*

Hosts: Polyphagous - Citrus, Crataegus, Prunus, Mangifera, Persea 29

Distribution: Mozambique 5, Italy, Jamaica, guayana 72, Algeria 9, Rhodesia 54, Morroco, Egypt 40, S. Africa 20, Turkey 25, Portugal 86, Spain 49, Canary Isl.,Madeira Isl., Fiji, Seychelles 11, Brazil 95, Thailand 98, Madagascar 73, Reunion Isl. 74, Iran 19, Kenya 38, Nigeria 78, India 3, St. Helene Isl. 75, USSR (south central region) 27.

Slides in collection: Australia, China, Java, Philippines, Indonesia, Sri. Lanka, Singapore.

Gen./yr:

Location on Host: Leaves, fruit.

Economic Importance: A pest in South Africa 20.

On citrus in Turkey 25.

In Madeira one of most injurious pests 10.

Diaspidiotus prunorum (Laing)

Turan Oyster Scale

Consideration status: Important pest*

Hosts: Amygdalus, Cerasus, Crataegus, Cydonia, Malus, Persica, Prunus, Pyrus Sorbus, Corylus, Ribes 29

Distribution: Uzbekistan 4, Armenia, Turkestan, Pakistan, Kazakstan, Iran 93, Gruzia, Afganistan 35, Tadzhikistan 16, Azerbaidzhan 55, Georgia (USSR)

Generations/year: 2, in Gorno- Badakhdhan Region(Pamir), Tadzhikistan 16, overwinter as second instars 6

2, in Azerbaidzhan 55

2, in Uzbekistan, overwinters as females 27

Location on host: Woody twigs 12, 105

fruit leaves 105, 55

trunk and shoots 4

Economic Importance: Causes considerable damage to plum and almond in Armenia 106

Lepidosaphes malicola Borchsenius

Armenian Comma Scale

Consideration status: Important pest*

Hosts: Armeniaca, Cerasus, Malus, Mespilus, Pyrus, Persica, Rosa, Juglans Ribes 29, Polyphagus

Distribution: Armenia 14, Iran 56, Tadzhikistan 17, Ukraine 103, Georgia (USSR) 52

Generations/year: 2, in Armenia 28

overwinters in egg stage 7

2, Georgia 52

Location on host: Trunk, branches, leaves, stems, fruit 14

Economic Importance: Causes deformed fruit; circular red areas where scale is attached 14

Serious pest of apples in southern Armenia 104

Parlatoria cinerea Hadden

Tropical gray chaff scale

Consideration status: Important pest*

Hosts: Citrus, Mangifera, Bougainvillaea, Rosa, Jasminum, Gardenia, Viburnum 29, Grewia, Melia, Malus, Nerium 60.

Distribution: Brazil, Thailand, Philippines, China, Society Isl., Samoa, Mexico, Indochina, Taiwan, Cuba, Dominica, Grenada, Haiti, Jamaica, Montserrat, St. Lucia, Trinidad, Argentina, Suriname, Italy, Spain, Israel, S. Africa, Java, Str. Settlements, Tahiti, India, New Caledonia, Marquesas Isl. 80, S. Mariana Isl. 18, Bonin Isl. 59, Japan 58, Guam 41, Pakistan 60, Mozambique 5, Lebanon 108, Colombia 81, Cook Isl. 112.

Slides in Collection: Panama, Pitcairn Isl., Paraguay, Peru, S. Africa, New Zealand, Venezuela, Chile, Hong Kong.

Generations/year: Populations intermingled with Parlatoria pergandii which has 3-4 generations. All stages in Israel throughout year 44.

Location on host: Trunk, branches, leaves, fruit 45.

Economic Importance: An important pest in Israel. Minor importance in Italy, Spain, and Brazil 99.

In Israel P. pergandii dominates in summer and P. cinerea in winter 44, Most of damage attributed to P. pergandii in some areas was in fact caused by P. cinerea 43.

Parlatoria crypta McKenzie

Consideration status: Pest

Hosts: Citrus, Ficus, Pyrus, Morus 93, Malus, Rosa, Melia, Mallotus, Mangifera, Euonymus, Zizyphus, Jasminum, Olea, Nerium, Cordia 29, Juglans 35, Laurus 13, Calotropis, Albizzia 94, Asparagus, Clerodendron, Diospyros, Hibiscus, Vitis, Bauhinia, Eugenia 1, Ehretia, Musa 46

Distribution: India, Iran, Iraq 93, Pakistan 47, Comoro Isls. 76, Sudan 92

Slides in Collection: Philippines, Morocco, St. Lucia, Egypt, Dom. Rep., Trinidad, Italy

Generations/year: 2, 92

Location on host: Stems, leaves, fruit 92

Economic Importance: Major pest of mango in Sudan 92.

Quadraspidiotus lenticularis (Lindinger)

Round olive scale

Consideration status: Potential pest

Hosts: Pyrus, Prunus, Crataegus 30, Olea, Populus, Quercus, Ficus, Betula, Euphorbia, Pistacia, Rhamnus, Fraxinus 29, Juglans, Gleditsia collection

Distribution: Australia 30, Morocco, Canary Isl., Yugoslavia, France, Switzerland, Italy, Greece, Crimea 12, Hungary, Denmark, Spain 62, Bulgaria 69, Spain 50, Turkey 67, Ukraine 102, Iran 39.

Generations/year:

Location on host: woody stems (trunks, branches) 30

Economic Importance: Not economic on apple & plum in Australia 30. Not economic in Europe 12.

Quadraspidiotus marani Zahradnik

Southern Pear Scale

Consideration status: Important pest*

Hosts: Crataegus, Fraxinus, <u>Malus</u>, <u>Prunus</u>, Pyrus 29, Sorbus 62, Carpinus 34, Cydonia 109, Vitis 89

Distribution: Germany, Czechoslovakia, Poland, Hungary, Austria, Switzerland, Bulgaria, Italy, France 116, Yugoslavia 62, Turkey 66, Ukraine, Moldavia 34, Georgia (USSR) 65, Rumania 89

Generations/year: 1, overwinters as fertilized adult females, bisexual 91

Location on host: Trunk, branches 66

Fruit 34

Economic Importance: Most damaging to apples in Eastern USSR, widespread in commercial orchards and back yards 61.

On stone fruit especially plum in Rumania 90

A serious pest in Yugoslavia 70

Quadraspidiotus pyri(Lichtenstein)

False San Jose Scale

Consideration status: Important pest*

Hosts: Amygdalus, Cerasus, Crataegus, Malus, Mespilus, Prunus, Pyrus, Sorbus, Spirea, Populus, Salix, Juglans, Betula, Carpinus, Ficus, Platanus, Aesculus, Tilia, Fraxinus, Olea 29, Alnus 42, Ligustrum 101, Cydonia, Cornus 109, Vitis 64

Distribution: France, Switzerland, Germany, Italy, Hungary, Crimea, Caucasus, Ukraine, Spain, Algeria, Morocco, Egypt, Israel 12, Belgium , Czechoslovakia 91, Iran 56, Yugoslavia 8, England 79, Tadzhikistan 17, Turkey 25, Australia 30, Greece 87, Canary Islands 51, Poland 63, Armenia 107, Azerbaidzhan 55, Bulgaria 109, Rumania 110

Generations/year: 2, France 21

Overwinters in Germany as second stage nymph, bisexual or parthenogenetic 91

Can tolerate temperatures to -25 or 30 degrees C in USSR 96

1, overwinters as second stage in USSR and Europe 102, 55, 28

Location on host: Woody branches, twigs, leaves, fruit primarily on apple 12

Economic Importance: Causes withering and weakening of fruiting branches 12

An important pest of peach, apple and pear, in northern Greece 88

Suturaspis archangelskyae(Lindinger)

White Pear Scale, Archangelskaya Scale

Consideration status: Pest

Hosts: Amygdalus, Armeniaca, Cerasus, Crataegus, Cydonia, Malus, Mespilus, Persica, Prunus, Pyrus, Punica, Punica, Fraxinus, Syringa, Populus, Juglans 29, Myrtus 57, Daphne 94

Distribution: Armenia, Uzbekistan, Turkestan, Turkmenistan, Tadzhikistan, Iran, Iraq 93, Turkey 68, Georgia (USSR)

Generations/year: 2, Fertilized females overwinter, Fergana Valley, Tadzhikistan 6

1, ovoviviparous, Turkmenistan 83

Location on host: Woody branches and stems 13

Stems, twigs, fruit of pear 105

Economic Importance: Considered a pest in central Asia 13

Injurious on pear 104

Tecaspis asiatica (Archangelskaya)

Asiatic Plum Scale

Consideration status: Potential pest

Hosts: Amygdalus, Armeniaca, Cerasus, Cydonia, Persica, Prunus, Pyrus, Vitis 29, Ribes, Rosa, Syringa 82

Distribution: Armenia, Turkmenistan, Tadzhikistan, Uzbekistan, Iran 93, Turkestan 14, Afganistan 17

Generations/year: 2; overwinters as adult females 93

Location on host: Stems, branches, twigs, and leaves 93

Economic Importance: Prefers stone fruits 14

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